University of Texas Bulletin
No. 2333: September 1, 1923

THE GEOLOGY AND NATURAL RESOURCES OF COLORADO COUNTY

BY

T. L. BAILEY

Bureau of Economic Geology and Technology
Division of Economic Geology
J. A. Udden, Director of the Bureau and Head of the Division

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of democracy. . . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

Mirabeaú B. Lamar

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THE GEOLOGY AND NATURAL RESOURCES OF COLORADO COUNTY

By T. L. BAILEY[1]

Colorado County is situated entirely within the rectangle formed by parallels 29 and 30 degrees north latitude and meridians 96 and 97 degrees west longitude, the center of the county being a little north of the center of this rectangle. This county is essentially an irregular rectangle in shape with the boundary lines running northeast-southwest and northwest-southeast respectively. Its average width from northwest to southeast is 26 miles while from northeast to southwest it is 29 miles. The maximum width from north to south is 46 miles including the southwest neck of the county, and from east to west 39 miles. The total area of the county is approximately 948 square miles. The northeastern boundary of the county is the San Bernard River with the exception of about seven miles which lies northwest of its head waters. Also the Navidad River forms the western boundary for about four and a half miles. The other boundaries are arbitrary surveyed lines. The Colorado River flows southeast across the center of the county.

ACKNOWLEDGMENT

Special acknowledgments are due to a large number of the citizens of Colorado County for their kind hospitality and for facilitating the work of the writer in several ways, such as by giving information of the country and roads, personally conducting the writer over certain portions of the county, and furnishing fossil specimens, well logs and other data. Special mention is due County Judge John C. Hoyo for keeping the writer in touch with the landowners of the county, and otherwise facilitating the work. Messrs. H. W. Patrick and James Dickson of Rock Island, Messrs. Ben Faber, county engineer, and Emil Rabel, tax collector of Colorado County, Messrs. Henry Seifert and Otto Barta

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[1]Manuscript submitted August, 1923. Publication issued November, 1923.

of Weimar, Mr. M. E. Newson of Osage, Mr. R. H. Beyer and two sons of Ellinger, and Dick Vogelsang of New Ulm personally conducted the writer over considerable parts of the county and gave other important assistance. Mr. O. A. Zumwalt and August Ilse of Columbus, Frank Janecka of Weimar, and other gentlemen kindly contributed fossil specimens and Messrs. A. C. McClanahan of Eagle Lake and C. M. Staples, division engineer of the G. H. & S. A. Ry. furnished well logs. There are many other residents of the county who have assisted in various ways but lack of space precludes separate mention.

The elevations of railroad stations included in the report were kindly furnished the writer by the division engineers of the G. H. & S. A., S. A. & A. P., and G. C. & S. F. railroads.

Dr. E. H. Sellards also aided the writer very materially by spending four days in the county with him. The writer also wishes to express his appreciation of the kindness of Mr. Alexander Deussen, consulting geologist, and Mr. E. T. Dumble of the Rio Bravo Oil Company, who have had wide experience with the formations found in Colorado County and who freely gave the writer their ideas of these formations and other problems connected with the work on Colorado County.

LITERATURE

There is practically no literature on the geology of Colorado County up to the present time although this county is included in a "Geologic Map and Sections of Texas East of the Ninety-Seventh Meridian," by Alexander Deussen, published in 1914 with Deussen's report on the "Geology and Underground Waters of the Southeastern Part of the Texas Coastal Plain" (U. S. G. S. Water-Supply Paper, 335). The mapping and nomenclature of formations differs a good deal from that of the present writer, but this map was of considerable assistance. The text of Deussen's report does not mention Colorado County specifically and in fact his report does not include any territory west of the

Brazos River. However, Deussen's description of formations which occur in Colorado County as well as farther east was of much assistance.

"The Geology of East Texas," by E. T. Dumble (Univ. of Tex. Bull. No. 1869) contains about the most detailed descriptions of the same formations that are exposed in Colorado County that were available, although Colorado County is west of the area reported on by Dumble. Much valuable information was obtained from this paper on the lithology and stratigraphy of Upper Tertiary and Quaternary formations of the Gulf Coastal Plain.

The only mention of the geology of Colorado County that could be found in literature was in Dumble's article on "The Cenozoic Deposits of Texas" (Jour. of Geol., Vol. 2, No. 6, p. 560) in which he mentions that deposits similiar to the Lapara of the type locality on the Nueces River "were observed between La Grange and Columbus."

Wm. B. Phillips in his "Mineral Resources of Texas" (Univ. of Tex. Bull. No. 365) mentions clays and gravels as mineral resources of this county but states the resources have not been fully investigated.

A paper by Alexander Deussen entitled "Geology of the Coastal Plain Region of Texas" (U. S. G. S. Prof. Paper, 126) is now in press and will probably appear in the near future. This paper brings the knowledge of the coastal plain Tertiary and Quaternary formations more up to date and will doubtless be a very valuable contribution.

BASE MAPS AND GEOLOGIC MAP

The principal maps used in preparing this report and the accompanying geological map were the Cat Spring, Ellinger, Alleyton, Borden, and Schulenburg Quadrangles and a small portion of the Wallis Quadrangle of the Advance Sheets of the progressive Military Maps published by the Southern Division, Corps of Engineers, United States Army. A number of inaccuracies were noted both in the topography and drainage and these errors in drainage have been corrected, wherever observed. The railroads and roads are mostly quite accurate although several minor changes have been made in the courses of both, especially in that of the main east-west highway (Texas State Highway No. 3) since the field work of the army engineers was completed (1913). These changes have also been entered on the map which accompanies this report. These maps cover only that portion of Colorado County north of latitude 29 degrees and 30 minutes.

The Land Office map of Colorado County was also used in checking locations on the military maps and to a considerable extent in mapping the geology in the southern part of the county. The drainage shown on this map is probably more accurate than on any other map but not all the creeks are entered, nor are any of the roads.

The road map of Colorado County obtained from the State Highway Commission was of some assistance as indicating the principal roads of the county. The roads south of latitude 29 degrees and 30 minutes which are shown on the geologic map are taken from the road map supplemented by additional data obtained by the author. However, the road map is of much smaller scale than the other maps used so that the roads south of an east-west line running through Cheetham (Lat. 29 degrees 30 minutes N.) are only approximately located.

The geologic mapping was done without a plane table or transit but is believed to be quite detailed considering the scarcity of exposures in this region of slight relief.

CLIMATE AND RAINFALL

The climate of Colorado County may be classed in a general way as a fairly moist warm temperate. The temperature rarely exceeds 100 degrees Fahrenheit in summer nor does it often fall below 30 degrees in midwinter. In fact, citrus fruits are successfully grown in the southern part of this county.

The average rainfall is about 35 inches per annum and is distributed throughout the year although the heaviest rains are in winter and spring. Droughts of three to six months duration are sometimes experienced in summer and fall.

TOWNS, RAILROADS AND ROADS

The population of Colorado County as given in the 1920 census is 19,013. The principal towns are Eagle Lake, Columbus, and Weimar. Among smaller towns are Garwood, Rock Island, Frelsburg, Oakland. Alleyton, Altair, Glidden, Provident City, Sheridan, Calhoun, Matthews, Pisek, and Bernardo.

There are five railway lines in Colorado County. The main line of the Galveston, Harrisburg and San Antonio (Southern Pacific System) runs in a northwest-southeast direction across the county. The La Grange Branch of this railway runs northwest from Glidden to La Grange in Fayette County. The San Antonio and Aransas Pass Railroad traverses the southern part of Colorado County in a northeast-southwest direction; the Gulf, Colorado and Santa Fe lines (Cane Belt Branches) extend north and south through the eastern and southeastern portion; while the Missouri, Kansas and Texas Railroad cuts across the extreme northern point of the county.

There is one good gravel road (Texas State Highway No. 3) that parallels the main Southern Pacific line and connects the three largest towns. This is part of the San Antonio-Houston Highway. There are no other macadamized roads in the county with the exception of short stretches around Eagle Lake and Columbus. Most of the dirt roads are almost impassable for automobiles after long wet spells. As a whole the county is fairly well supplied with roads although most of them are second and third class. The southwestern parter, which is the most sparsely settled portion, has very few roads of any description and many of these are impassable for automobiles.

TABLE OF ELEVATIONS OF RAILWAY STATIONS IN COLORADO COUNTY. ELEVATIONS TAKEN AT TOP OF RAIL IN FRONT OF DEPOT, SEA LEVEL DATUM.

Alleyton (G. H. & S. A.)	189
Altair (S. A. & A. P.)	204
Boedecker Junction (G. C. & S. F.)	144
Borden (G. H. & S. A.)	295
Calhoun (G. C. & S. F.)	160
Cheetham (S. A. & A. P.)	264
Chesterville (S. A. & A. P.)	156
Columbus (G. H. & S. A.)	201.4
Eagle Lake (G. H. & S. A.)	174
Eagle Lake (S. A. & A. P.)	167
Eagle Lake (G. C. & S. F.)	170.6
Eagle Lake Junction (G. C. & S. F.)	172
Eldridge (G. C. & S. F.)	143.8
Englehart (G. C. & S. F.)	153
Garwood (G. C. & S. F.)	140.8
Glidden (G. H. & S. A.)	234
Glidden Junction (G. H. & S. A.)	244
Haney (G. C. & S. F.)	149.6
Herbert (G. C. & S. F.)	140.4
Knarf (G. H. & S. A.)	258
Lakeside (G. C. & S. F.)	172
Lorine (G. H. & S. A.)	314
Matthews (G. C. & S. F.)	171.3
Pisek (M. K. & T.)	290
Ramsey (G. H. & S. A.)	225
Rayner Junction (G. C. & S. F.)	171.6
Riceland (G. C. & S. F.)	171.6
Rock Island (S. A. & A. P.)	248
Sheridan (S. A. & A. P.)	279
Slutter (S. A. & A. P.)	175
Vance (G. C. & S. F.)	159.6
Weimar (G. H. & S. A.)	408
Womack (G. C. & S. F.)	157.3

COAST AND GEODETIC SURVEY ELEVATION

H 7.—About 3.5 miles west of New Ulm, Austin County, on the Missouri, Kansas and Texas Railway, 6 meters east of mile post 1010, in the corner of the right-of-way and cattle-guard fences. A stone post with square hole in top. Elevation—359.032 feet.

TOPOGRAPHY AND DRAINAGE

Colorado County occupies almost the geographic center of the Texas Gulf Coastal Plain, for it is midway between the Red River at the Arkansas-Texas border and the Rio Grande at Rio Grande City and also half way between the Balcones scarp at Austin and the Gulf. (See fig. 1.)

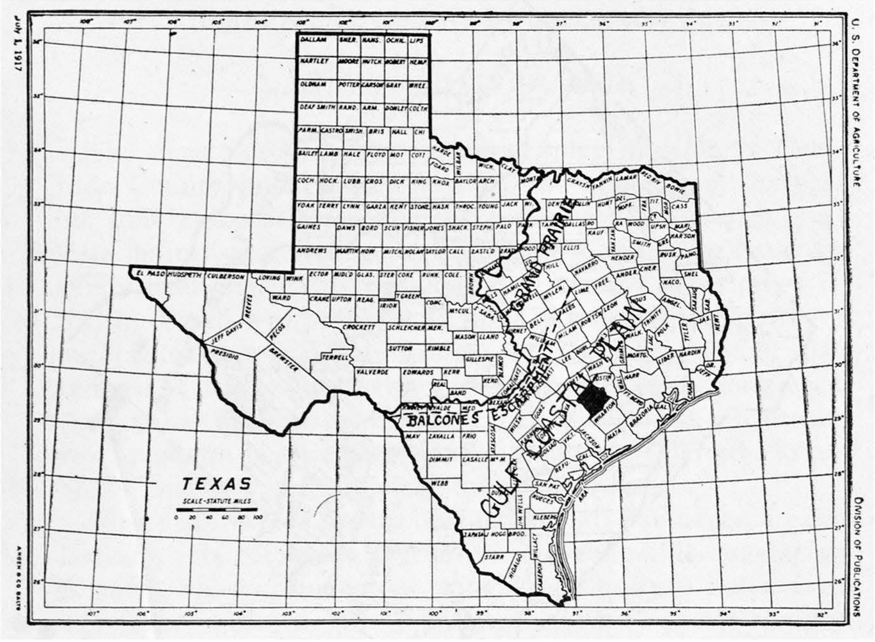

Fig. 1. Outline map of Texas showing location of Colorado County with respect to the major physiographic divisions of the state.

RELIEF

The highest points in Colorado County are found near the county line two miles northeast of Frelsburg, near the point where the M. K. & T. Railway crosses the northeastern county line, elevation 425 feet, and in the neighborhood of Weimar, elevation 415 feet. The lowest point, about 125 feet, is found where the Colorado River crosses the southeastern county line one mile east of Nada. This gives a maximum relief of 300 feet. By far the greatest difference in relief occurs in the northwestern half, the steepest slopes being found along the Colorado River and Cummins Creek, between Columbus and the Fayette County line.

There is a gradual regional slope to the southeast but this is interrupted by a greatly dissected northeast-southwest divide near the base of the Lissie formation. This

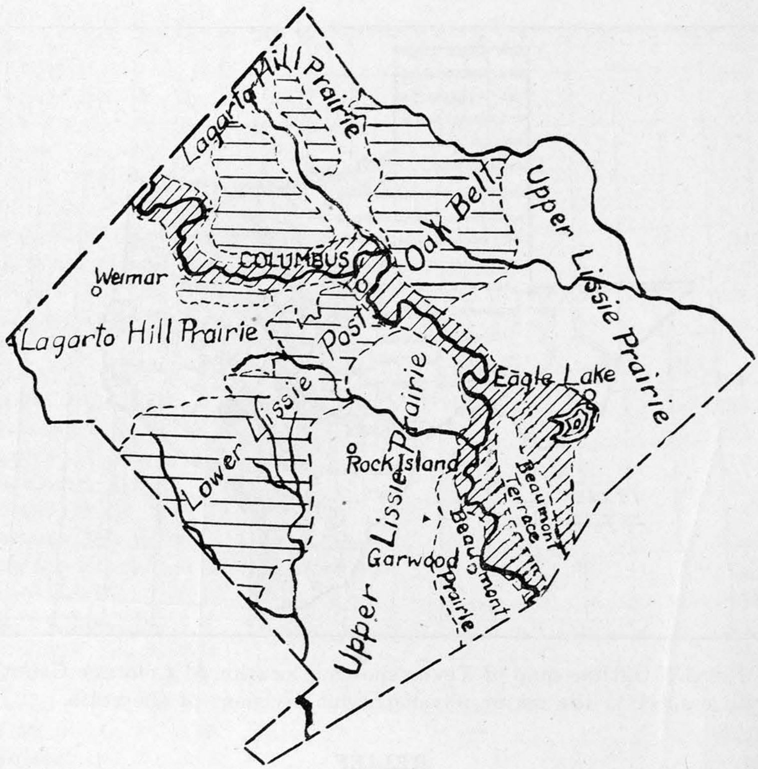

Fig. 2. Outline map showing topographic divisions of Colorado County. (Horizontal ruling indicates Lower Lissie Post Oak Belt; inclined ruling indicates river bottoms and younger terrace.)

low divide is caused by the outcrop of the southeastward-dipping Lower Lissie gravels. However, this divide is the remnants of high seaward-facing terraces and the county can hardly be said to have cuesta topography.

The portion of the Gulf Coastal Plain in Colorado County can be subdivided into four topographic belts which extend roughly from northeast to southwest. These are, beginning at the northwest: (1) Lagarto Hill Prairie; (2) Lower Lissie Post Oak Belt; (3) Upper Lissie Prairie; (4) Beaumont Black Land Prairie; and (5) River Bottoms and Recent Terraces. These divisions are shown in figure 2.

PHYSIOGRAPHIC DIVISIONS IN COLORADO COUNTY

LAGARTO HILL PRAIRIE

The most northwesterly physiographic division in Colorado County and that formed by the outcrop of the oldest widely exposed geologic formation (the Lagarto), consists mainly of a rolling, treeless prairie with black clay or sandy loam soil. This belt averages about twelve miles in width. Patches of post oak and live oak timber occur where outliers of Lower Lissie gravel cap the Lagarto and also fringes of larger and more varied timber occur along even the smaller streams in this belt. In general the slopes are rather gentle in this area, except along the Colorado River bluffs, but they are sufficient for good drainage.

There are a few poorly drained slough-like areas, in the lowest parts of which a crust of salt that kills vegetation forms. The two principal sloughs of this type noted are: (1) Three miles north of Weimar, at the Fayette County line, partly on the land of Frank Walzel and (2) two miles south of Borden, on the land of H. C. Greak and Ed. Barton. Both "sloughs" extend nearly east and west, are about one mile long and two hundred yards wide. The former drains into the Colorado River and the latter into Skull Creek. These look like rather poorly developed headwater drainage.

The topography of the Lagarto Hill Prairie has reached a stage of middle or later maturity, although considerable rejuvenation has occurred recently as shown by the well developed terraces of even minor streams.

The highest points in the county are in this topographic belt or in the northeastern part of the county near the contact with the Post Oak Belt. The largest area over 400 feet in elevation is around Weimar. This consists of a nearly level-topped sand ridge that has been dissected into two parts by a small northward-flowing branch of Middle Harvey Creek. The oval-shaped area, 400 feet more or less in elevation, is about three and one-half miles across in an east-west direction and has a maximum extent of three miles north and south. This forms the divide between the Navidad and Colorado drainage. However, this divide, which extends northwest-southeast, gradually becomes considerably lower to the southeast, reaching a maximum height of 330 feet and about 50 feet above the nearby stream beds between the headwaters of Middle Sandies Creek and Miller Creek in the Post Oak Belt. This grades off to an almost imperceptible divide at Rock Island which is only 250 feet above sea level.

The soil of the Lagarto Hill Prairie is principally a sticky black clay containing an abundance of lime and making very fertile farming land. This is formed from the outcrop of Lagarto marly clays. However, where areas of Lagarto sandstone outcrop the soil is a sandy loam or sand, as on the sand hill east of Weimar and northwest of Glidden. Part of the river hill country north of the Southern Pacific Railroad between Glidden and Borden especially on the ridge next to the river bottom is a grass-covered, bare prairie with the sandstone coming to the surface very frequently and with very thin soil between these outcrops.

LOWER LISSIE POST OAK BELT

Succeeding the Lagarto Hill Prairie to the southeast is a strip of rolling sandy and gravelly territory, locally called "sand ridge" or "gravel ridge" country, practically all of which is densely wooded. However, small patches of prairie sometimes occur in the midst of this belt as noted south of Glidden. Post oaks are the predominant trees and seem to flourish equally well on gravel and sand hills and in the valleys between. This area thus contrasts sharply with the rest of the county, except for the river bottoms which are also wooded, although with dissimilar timber. The majority of the trees in the Post Oak Belt attain no more than a rather small size. A thick shrubbery undergrowth often exists also. An illustration of this post oak timber is shown in Plate V, figure 1.

The width of this belt varies from eight to fifteen miles. In the area between the Colorado River and Cummins Creek and fringing both bluffs of these streams the Lower Lissie belt is the most prominent formation, for the Lagarto is mostly capped with large outliers of Lower Lissie gravel. In fact this terrace formation with its attendant post oaks extends considerably northeast of the Colorado County line along the Colorado River. The creeks flowing through this belt generally have broad sandy beds, the best example of which is Big Sandies Creek and its branches.

The soil of this topographic belt is mainly either a reddish, gravelly or clayey sand or a dirty buff almost pure sand. It is of very little value for agriculture and does not even make a good pasture, although most of it is used as pasture land. The poorest land in the county is found in this division. Some of the buff sand especially in the vicinity of the headwaters of Sandies and Miller creeks is probably wind-blown although most of it is residual from the Lissie formation, the clay portion being carried off more readily by water. The prevalence of the loose sandy or gravelly soil seems to be responsible for the development of the timber.

Near the contact of the Lissie formation with the Lagarto extending in a northeast-southwest direction from New Ulm to Shimek is a greatly dissected and ill-defined divide. This is shown by the presence of a line of old terrace hills that are higher than the surrounding country and by the diversion of several of the tributary streams from their normal southeast flow for at least a portion of their courses. The most prominent of the hills is Rocky Hill, three miles southwest of Glidden. The sand and gravel ridges near the headwaters of San Bernard and Little Bernard rivers and Piney, Skull, Miller and the

Sandies creeks are less prominent examples. The northeastward flow of Radliff Creek and of the headwaters of Skull and Miller creeks and the northwestward flow of the upper reaches of Piney Creek are examples of the departure of streams from their normal courses. The high terrace gravels at the base of the Lissie are mainly responsible for this low divide in Colorado County.

Minor topographic features that often occur on the flatter portions of the Lower Lissie Belt, especially noteworthy where sparsely wooded as in the plain south of Glidden, are low gravel and sand mounds that usually support a thick growth of live oak trees while the areas between support only grass or yaupon and other brush.

UPPER LISSIE PRAIRIE

In marked contrast to the Lower Lissie Post Oak Belt is the next succeeding topographic belt to the southeast, the Upper Lissie Prairie. This is entirely treeless except in the bottoms of the larger streams such as the Colorado and San Bernard rivers and Sandies and Skull creeks.

The Upper Lissie Prairie is typically an almost flat, grass-covered prairie. The general impression obtained from a wide view of much of this belt is one of featureless flatness. The general slope of this plain is east-southeast in the southeastern and eastern portion of Colorado County and south-southeast in the south-central portion. This difference in regional slope is noted by comparing the course of the San Bernard River with that of Sandies and Pin Oak creeks. The divide between these two contrasted portions of eastern and southern Colorado County is surprisingly close to the Colorado River in the vicinity of Garwood. East of this town Mustang Creek, which is part of the Navidad drainage, flows within less than two miles of the present bed of the Colorado River. A notable feature of the Lissie Prairie is the presence of mounds and depressions which are later more fully described.

The Upper Lissie Prairie passes gradually into the Lower Lissie Post Oak Belt. The prairie in general becomes distinctly rolling near its junction with the Lower Lissie outcrop and this rolling character extends as much as five or six miles from the edge of the post oaks between Bernardo and Eagle Lake and between Columbus and Altair. However, the timber belt usually has a rather definite southeastward and eastward limit, the transition between typical post oak woods and open grassy prairie often takng place within a zone only a few hundred yards wide. The trees are progressively smaller and more scattered on the prairie side of the contact, finally becoming small clumps of live oak brush only a few feet high occurring only on the small mounds mentioned below which are better drained than the surrounding prairie. Sometimes a larger gravel mound although situated as much as a mile from the edge of the Post Oak Belt supports a dense growth of fairly large live oak trees. This same gradation is observed in the timber fringes along the larger streams flowing through the Upper Lissie. However, the smaller streams like Pin Oak and Mustang creeks in Colorado County in some places have no timber whatever along their courses, and when trees are present they occur only as a single line of live oaks and other trees. These same streams have developed practically no flood plain or bottom, which seems to account for this fact.

The general soil of the Upper Lissie Prairie is a pale buff loamy clay or sandy loam although patches of more sandy or even gravelly soil occur quite commonly. This soil after it has once been thoroughly soaked becomes nearly impervious to water and after continued hard winter or spring rains, water often stands on considerable areas of level prairie for several days while the shallow bowl-shaped depressions mentioned previously and described in more detail later often contain water during the greater portion of the year. The drainage of this topographic division is necessarily poor and the land is therefore well-adapted for rice growing.

MOUNDS AND SINKS

Description.—Small mounds and basin-shaped sinks or depressions, as well as a few much larger mounds, are characteristic minor topographic features of the Upper Lissie Prairie and thousands of them may occur within an area of a few square miles. Mounds and sinks generally occur together although the mounds are often found over considerable areas where sinks were not noted or are very scarce. But no sinks of this type were noted without mounds occurring nearby. Both are numerous and typically developed on the open prairie in the vicinity of Rock Island, and south from there to the county line. However, they are more or less commonly developed throughout the Upper Lissie Prairie Belt.

The mounds are generally circular but may be elliptical in outline, have a diameter of from five to several hundred feet and rise from a few inches to twenty feet above the surrounding prairie. The majority of them have a diameter of about twenty-five feet and a height of two feet. They are locally called "gas mounds" or "gopher mounds." The spaces between mounds are flat, not concave. The large mounds will be discussed later. The small mounds sometimes occur in semi-circular lines or rows but more commonly are found in irregularly scattered groups being much more abundant in certain small areas than in others nearby. Sometimes two or more are found so close together as to form a composite mound. Some of them support a growth of low oak brush while others are covered with tall weeds or high grass, unlike the vegetation between mounds. However, the vegetation on many of them is similar to that of the surrounding prairie. These small mounds are illustrated in Plate VI, figure 1.

The soil of these mounds often does not appear to be different from that of the surrounding prairie but in many it is distinctly sandier and in a few cases very gravelly. Some of the smaller mounds have a number of ant hills on their surface.

The sinks associated with the mounds are generally nearly circular in outline and vary in diameter from eight feet to six hundred feet or more. The majority of the sinks are considerably larger than the mounds, one to two hundred feet being the commonest diameter. The bottom of these sinks is from a few inches to five feet lower than their rims. The rims are in many cases slightly raised but probably the majority of them are not. Water stands in these depressions during the greater part of the year and they are then called "prairie ponds" and are the gathering places for large numbers of wild ducks during the winter. Practically all of them are dry during the summer and early fall and their bottoms are bare and sun-cracked, but no salt was observed in any of them. Reeds, sedges and other water-loving plants are commonly found around the edges of the sinks, but often there is no difference from the surrounding prairie except that the grass is higher. A sink is illustrated in Plate VI, figure 2.

Several residents of the county have made interesting observations on the growth of these mounds and sinks and similar phenomena are commonly reported from other Gulf Coastal Plain counties.

The most interesting of these observations was made by H. W. Patrick, a resident of Colorado County, who lives three miles south of Rock Island. Mr. Patrick built his house in 1905 and reports that the ground underneath the house was practically level at that time. The foundation was laid on stout piles so that it stands about three and one-half feet above the ground. The base of each pile was buried about three feet in the ground before building commenced. In 1922 the flooring of two rooms had become so rotten that it had to be replaced. Mr. Patrick's surprise was great when he found that a mound about twenty feet in diameter had risen up under the house and was in contact with the floor, thus causing it to rot. This growth all took place in seventeen years according to Patrick's statement. The writer's observations seem to confirm this statement for the sides of the house except near the mound are still three and one-half feet above the ground although the mound, which was leveled off somewhat at the time the new flooring was put in was almost touching the floor of much of the center of the house when observed in December, 1922. No ant hills were noted on this mound.

In the barnyard of the Patrick place is a small sink about two feet deep and eight feet in diameter which has formed and grown larger within the last three years in spite of attempts to fill it up. That the sinks were originally mounds, at least in a great many instances, can scarcely be doubted for transition stages between mounds with a perfectly convex surface through those with a very slight depression in the center to mounds that have entirely sunken except for a crescent shaped area around one edge were observed in a number of localities. Every gradation between mounds and sinks can be seen within the space of a few acres in H. W. Patrick's pasture.

ORIGIN OF MOUNDS AND SINKS

The origin of the mounds has been a much mooted question and no entirely satisfactory solution of all of them has been found. In fact they have been termed "inexplicable mounds" by at least one author. Volume 23 of *Science* for 1906 contains several articles on the origin of small mounds and most of the possible theories of their origin are contained in these articles although a number of other good articles have appeared. The principal writers on this subject are: Udden,[1] Hill,[2] Campbell,[3] Veatch,[4] Dumble,[5] and Hobbs.[6] There is considerable disagreement among these authors as to the mode of formation of these mounds but

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[1]Udden, J. A., The Origin of Small Sand Mounds in the Gulf Coast Country, Sci. N. S., V. 23, p. 849, 1906.

[2]Hill R. T., On the Origin of the Small Mounds of the Lower Mississippi Valley and Texas, Sci., N. S., V. 23, pp. 704-706, 1906.

[3]Campbell, M. R., Natural Mounds, Jour. Geol., V. 14, p. 708.

[4]Veatch, Geology and Underground Water Resources of Northern Louisiana and Southern Arkansas, U. S. G. S., Prof. Paper 46, pp. 55-59, 1906.

[5]Dumble, E. T., Geology of East Texas, Univ. of Tex. Bull. No. 1869, pp. 272-274, 1918.

[6]Hobbs, Some Topographic Features Formed at the Time of Earthquakes and the Origin of Mounds in the Gulf Coastal Plain, Am. Jour. Sci. 4, V. 23, p. 245, 1907.

there is probably a larger number of exponents of the "ant-hill theory" than of any other. Mounds of similar appearance to many of these in Colorado County are found over large areas in the Texas and Louisiana Gulf Coastal Plain as well as in Arkansas, Missouri, Oklahoma, Kansas, southern California, northeastern Washington, Mexico, and northern Alaska both in open prairies and in wooded areas.

One condition that seems to be practically essential to mound preservation if not to their formation is the presence of an almost level plain. Even if they could be formed in distinctly hilly or mountainous country they could not withstand the onslaught of rapidly moving water long and hence would not be preserved. They might be formed in a country of low hills and some are mentioned in a hilly country by Veatch. On account of their similar physiographic occurrence there is a natural tendency to assume the same origin for all these mounds even in widely separated areas while as a matter of fact similar mounds might be produced by more than one agency. It would seem more probable that at least the great proportion of the mounds in one geographic and physiographic unit like the Gulf Coastal Plain of Texas would have the same origin. It is a well-known fact that most of the largest mounds of the Gulf Coastal Plain of Texas and Louisiana contain cores of salt, gypsum and dolomite and are certainly unlike the myriads of small mounds commonly found in the same region. Yet it may be difficult if not impossible in certain cases to tell prior to drilling whether a given fairly large mound is a salt dome in its infancy or a large "prairie mound" of the type described above.

The following theories all of which have been previously put forward by other authors seem to the writer to be best fitted to explain the origin of the Colorado County mounds:

1. They are wind-blown sand accumulations that began to form around clumps of vegetation. These have become somewhat modified by rain erosion and are now covered by grass and other vegetation, but are probably still being added to at times of windstorms. The principal objections that have been advanced to the wind theory by Campbell, Udden

and others is their persistent symmetry and circular outline. The circular outline of most of the mounds, as well as the occurrence of coarse gravel on some of them, are real objections. However, some of the timber-covered mounds in the vicinity of Sandies, Skull and other creeks with sandy beds and flood plains, were probably formed by the wind. They apparently differ from the majority of the mounds in that they are more sharply convex and commonly if not generally elongated in outline. Their sides are not noticeably dissimilar in shape but may be slightly so. Their surface is composed entirely, not merely in the center, of sand. It seems probable that some almost round mounds may have a similar origin, the sand having accumulated originally around clumps of shrubs at the time of heavy windstorms. The irreularities, because they possess a greater surface in relation to their volume, are more rapidly attacked and rounding is the final result. Where there is a near and abundant supply of sand, dunes may be formed even where the climate is moist.

2. Some of the mounds are thought to be formed by differential erosion by rain and running water of resistant and non-resistant sediments. Most of the gravel mounds and mound-like ridges are thought to be of this type, the gravel lenses having formed a protective capping while the surrounding argillaceous sands or arenaceous clays are more easily eroded. The same result may have been produced, as Dr. Hill has suggested, by the differential settling of the coarse and fine sediments when soaked by periodic rains and the subsequent rounding off of the slightly compactable gravelly portions by water erosion. Mounds of this type are generally more or less elliptical or even greatly elongated in outline and support a growth of live oaks.

A typical example of these gravel mounds is found about two miles due north of Rock Island. It is about 1500 feet long, 800 feet wide and rises about eight feet above the surrounding country. Its dimensions are rather uncertain because the prairie is silghtly rolling here. The top of this mound is covered by a dense canopy of live oaks which reach a height of about 25 feet although there are no trees within a mile of this mound in all directions. This is larger than many of the gravel mounds. No traces of animal burrows have been noted. The mounds of the Lower Lissie Belt are probably largely of this type although the gravel is often covered by a few inches of wind-blown sand.

3. Mounds are formed by the work of ants. This theory is adhered to by more of the writers mentioned above than any other single theory. Veatch, who has discussed this theory fully considers the mounds to have been produced by the work of the atta (leaf-cutting) ants or by termites (white ants). Mounds of comparable size have been produced by the Atta ants in Cuba and the large mounds formed by the termites of Africa are well known. This theory assumes a very recent warm climate in this region and evidence of this is not satisfactory. However, many of the smaller mounds not over a foot in height could be produced by ants still existing in Texas. It is a common thing to find one or two ant hills on the smaller mounds in Colorado County, but probably the majority did not possess any. The growth of these mounds and the associated sinks in recent times and the absence of ant hills from many of those reported as growing excludes this mode of formation for at least a great many of the mounds. It seems more likely that the ants frequently build their hills on mounds because the mounds are better drained and that their presence is merely a result of the mounds being already present. However, many large ant hills were seen between mounds in sandier or more gravelly portions of the prairie.

4. Mounds may be produced by the rapid upward seepage of artesian waters from a porous sub-stratum through cracks or more porous places in the more impervious surface layer. This seepage is thought by the writer to take place only during rainy spells of considerable length such as are common in this region in winter and spring at which times considerable areas of the prairie are often covered with an inch or more of water. Hobbs supports a similar theory in a very much modified form for he considers the mounds to have been produced only during earthquakes

and cites instances of mud and sand volcanoes which were observed at the time of the New Madrid earthquake in support of his view. However, this portion of Texas is apparently not subject to such severe earthquakes as southern Missouri and the gradual observed growth of mounds as well as sinks would seem to discount this theory. Most of the contributions to literature on this subject have mentioned the "artesian vent or spring hypothesis" but very few seem to believe it explains the origin of many mounds. Dumble in his "Geology of East Texas," page 273, makes the following statement in regard to the origin of the small mounds:

"Small mounds in actual process of formation were noted one and a half miles southeast of Lovelady on the John Forbes grant in the post oak upland near the head of a small western tributary of Gail Creek, known as San Creek. Here, in a space some sixty feet in length, underlain by Yegua sand and light gray badland clay, are a half dozen small mounds close together and making up an elongated compound mound. From a half dozen small crater-like vents forming the summits of the mounds water in small quantities slowly oozes out, bringing upward with it materials varying in composition and texture from very fine clay to medium-grained sand, dark blue in color when fresh and a tawny yellow on the surface. The phenomena resemble closely those of a very quiescent stage of mud volcanoes. Forty feet of two-inch pipe was pushed by hand down one of these vents without reaching bottom."

No springs have been observed issuing from the summits of mounds in Colorado County by the author but he did not see any of the mounds after a very rainy spell when the prairie was thoroughly soaked.

However, some evidence on the constitution of a large mound near Rock Island is furnished from a boring with a soil auger made by Mr. John Baxter of Rock Island. The writer saw this boring only a few days after it was made and can confirm Mr. Baxter's report in general. This mound is located on the land of Mr. J. C. Young, two and one-half miles east-southeast of Rock Island. The mound covers about 10 acres, although it is difficult to delineate exactly, and is wide elliptical in outline, with the long axis running northwest-southeast, and is flattened slightly in the center. The height is from five to seven feet above different points in the surrounding prairie which is here slightly rolling. A hole was bored in the summit a few feet from the center and 15 feet of buff sand was passed through before striking the red, yellow and gray mottled Lissie sandy clay. However, the Lissie similar to that from the bottom of the hole is encountered only a few feet farther out from the center. A previous attempt was made to bore into the very center of this mound, but probably due to the very dry weather the sand here was packed so hard that the attempt was abandoned at a depth of two feet. From this boring it appears that there is a more or less funnel-shaped sand pipe extending downward from the center of the mound an unknown distance. This sand is foreign to the surrounding country and has evidently been brought up from below. It seems extremely improbable that this sand pipe could have been produced by animals of any kind and is cited as evidence for the artesian spring theory. The writer dug into some of these mounds when the prairie was fairly well soaked with rain in April, 1923, and found a layer of quicksand present often less than a foot below the surface.

The sinks, as seen in this county, from their common association with mounds and their observed gradation into partly sunken mounds, are believed to form on old mounds, whose artesian channels have become clogged. Later the gradual settling and compacting has caused the sinking. It seems likely, in the case of some large sinks, that some good-sized more or less open spaces or areas of very loosely compacted material must have existed underground or that hydrostatic pressure, later relieved by the stoppage of the circulation channels helped support the surface strata. A calcareous sandstone associated with a small amount of sandy limestone is encountered in wells at depths of 60 and 80 feet in this region but this limestone is apparently very local in distribution and over much of the area in which mounds are common is found at greater depths. The very nicely circular outline of the sinks as well as their well-developed symmetry would seem very unlikely to occur generally if the sinks were due to the solution of limestone some distance below the surface. They resemble small salines except that no salt was found or reported.

It is a widely disseminated belief over much of the coast prairie country that the small mounds and sinks are indicative of oil and are often called "gas blow-outs and gas mounds." Seeps of gas have been reported from some of the sinks in a few places but if gas is found it is only because a certain amount is present in the underlying rocks and happened to find its way into the channels along which the artesian springs rise, thus escaping with the water. It seems exceedingly improbable, if not impossible, from the wide distribution of the mounds and the small number of gas seeps reported, that gas plays any important role in the formation of these mysterious topographic features. Gas and oil seeps, when they do occur, are much more commonly found in the beds of streams.

LARGE MOUNDS OR MOUND-LIKE ELEVATIONS

There are a few mounds in Colorado County considerably larger than the ordinary "prairie mounds." The large gravel mound described above may possibly belong to this class but its origin is thought to be more probably as stated above. See the geologic map for the location of the large mounds noted by the writer. Since the topographic maps of the portion of the county in which the large mounds occur are rather inaccurate and have 25-foot contours, it has been impossible in the limited amount of time to tell whether or not some of the mound-like elevations may not be due to erosion. This is true of the rounded mound-like hill three miles north of Altair indicated on the geologic map. The large gravel mound north of Rock Island is also indicated on this map.

The best example of the large mounds and one whose existence can scarcely be due to erosion is located on Section 45 of the I. & G. N. R. R. Survey, nine miles west-southwest of Garwood and ten miles south-southeast of Rock Island on land now belonging to Rollington. The ranch house and two barns are situated on top of the mound. This is really a double mound with a slight but distinct saddle in the middle. This compound mound has an elliptical outline, its long axis extending east and west, and its diameter along this axis is about one-fourth of a mile. Its width is about half the length and it rises fully 20 feet above the surrounding prairie. It forms a good land mark for it can be seen for several miles in every direction. The saddle in the center is three or four feet lower than the two high points on each end. The soil on the mound is rather thin and is similar to that of the surrounding prairie, being derived from the Lissie formation. There is a large marshy place in the prairie north of the mound. A photograph of part of this mound is shown in Plate V, figure 2.

There is another large mound about two miles north of that just discussed near the southeast corner of the Nathan Mixon Survey. It is lower than the mound previously described, has a circular outline and several small prairie mounds occur on its surface. It also supports a growth of scrub live oak saplings although it is surrounded by open prairie. A small amount of gravel was observed on its summit but elsewhere the soil resembled that of the adjacent flat prairie.

Another mound shaped hill, on top of which is the outcrop of the older Lagarto formation surrounded by younger Lissie was noted two and one-half miles north of Frelsburg on the land of Louis Pflughaupt and Antonheinsohn, and others. This mound is situated in the hilly wooded portion of northern Colorado County.

ORIGIN OF LARGE MOUNDS

It is considered not impossible that at least one and possibly several of these large mounds are small salt domes, the elevation having been produced by the growth of a salt core below the surface at an unknown depth. However, no salt was observed on the surface of any of the large mounds although a small oil seep was found in a well on top of the large double mound described above. This will be discussed later under "Oil and Gas."

BEAUMONT BLACK LAND PRAIRIE

The Beaumont Prairie is similar to the Upper Lissie Prairie in being a flat featureless plain and in Colorado County the Beaumont is found typically in a belt from one to three miles wide bordering the Colorado River on the west side from two miles south of the mouth of Skull Creek to the Wharton County line.

The wide higher bottom lands extending from one mile south of Slutter, south to the Wharton County line on the west side of the Colorado River are also thought to be of Beaumont age and parts of them form a black land prairie also.

The second bottom of the Colorado River above Altair is also probably equivalent to the Beaumont in age and frequently contains black loam soil but much of it was originally wooded and it is generally unlike the typical Beaumont prairie near Garwood and near the coast.

This prairie forms a continuous belt paralleling the gulf coast on the gulf side of the Lissie Prairie in Wharton and other counties nearer the coast.

The principal difference between the Beaumont and the Upper Lissie Prairie is the character of the soil which in the former is sticky black clay ordinarily called "blackland" or "black waxy land." A low sand ridge, probably also in the Beaumont, parallels the river from Garwood southeast into Wharton County for several miles. All the rest of the Beaumont is black land in Colorado County and most of the best rice farms west of the Colorado River are located on the Beaumont. Those on the east side of the river are on the Upper Lissie, however. Practically all the Beaumont in Colorado County is cultivated which may explain the relative scarcity of the mounds described previously. However, these mounds are very abundant on the Beaumont nearer the coast.

The Beaumont Prairie occupies a slightly lower elevation than does the Upper Lissie but there is a very gradual gradation of one into the other as shown by the soil becoming progressively blacker and more clayey near the edge of the Beaumont outcrop.

RIVER TERRACES

The topography of Colorado County has been profoundly affected by the work of the major stream in the county, namely the Colorado River. In places there are as many as seven terraces developed. The upper three are considerably eroded and show their original terrace character only in places. These terraces grade downstream into seaward facing terraces or delta fringes in Colorado County. Thus the fifth, sixth and seventh terraces grade into the continuous belt referred to previously as the Lower Lissie Post Oak Belt, the third and fourth terraces into the Upper Lissie Prairie, and the second into the Beaumont Black Land Prairie. Alexander Deussen, in the United States Geological Survey Water Supply Paper 335, described the gradation of the upstream river terraces into inter-stream or coastward facing terraces farther downstream.

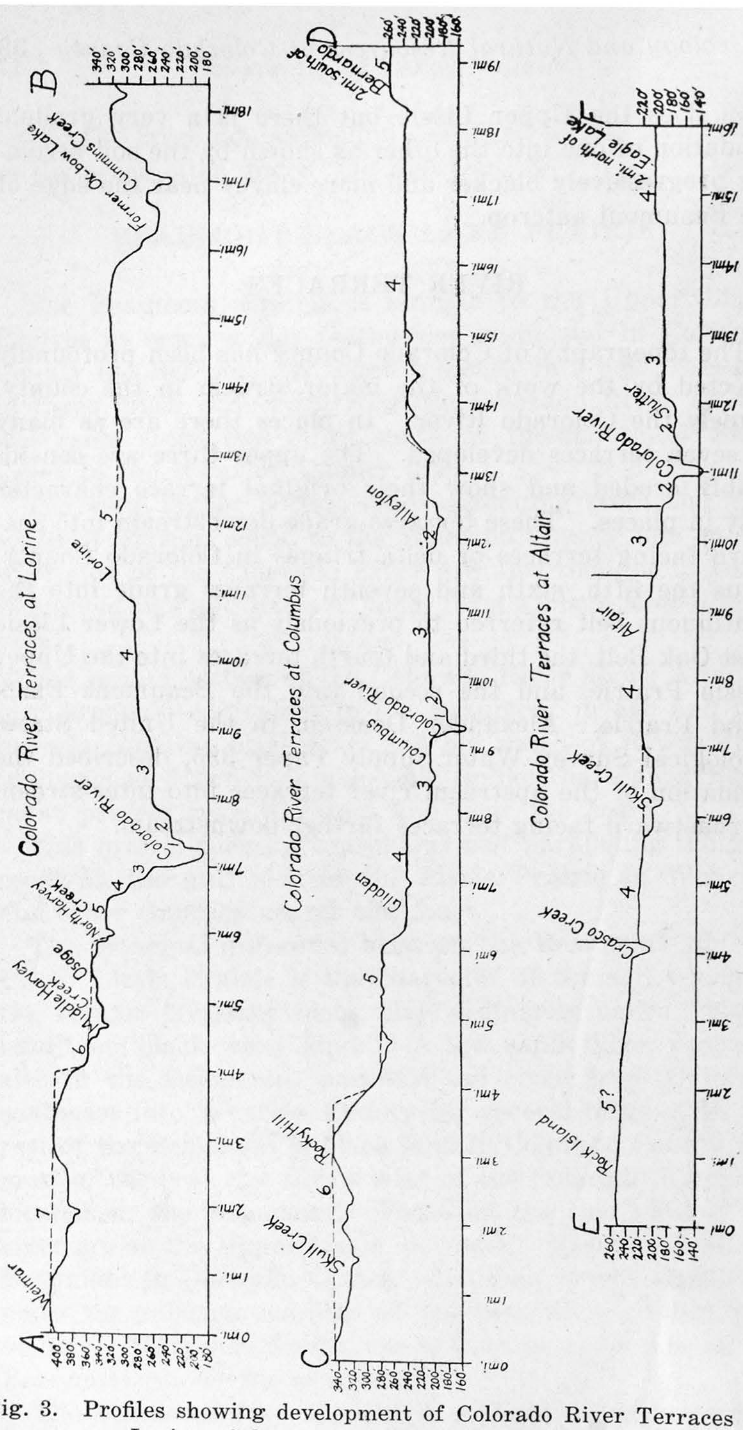

Fig. 3. Profiles showing development of Colorado River Terraces at Lorine, Columbus and Altair.

The profiles (figure 3) on page 34 of this report give a graphic representation of terrace development in Colorado County. Many of the minor irregularities of the terrace surfaces are omitted so that they appear somewhat more regular than they really are. Sections across the Colorado River and the adjacent territory are made along lines AB, CD, and EF, shown on the geologic map. These are made respectively at Lorine, Columbus and Altair.

The profile at Lorine gives an idea of all the terraces, on one side of the river or the other. The highest terraces, No. 6 and No. 7, are well developed on the southwest side of the river, although they have suffered considerable erosion.

Terrace No. 7 may be called in this county the Weimar terrace because the town of Weimar, which has an elevation of 408 feet above sea level is situated on its flat. This terrace is about 210 feet above the river. Weimar is one of the highest points in Colorado County and the adjacent portions of other counties and can be seen from considerable distances in all directions on account of this commanding location. The Weimar terrace has been cut in two by a northward flowing branch of Middle Harvey Creek so that there are now two high flats. Not much terrace gravel still remains on the Weimar terrace, although a few flint pebbles and cobbles can be generally found. Thus we see that the Lagarto Hill Prairie has been modified by river erosion but the terrace material is so scattered and forms such a thin veneer that it does not appreciably affect the soil and vegetation of the Lagarto Belt as outlined. The nearest point on this terrace is about four miles from the present Colorado River channel.

Terrace No. 6 is much more extensively developed in the western part of Colorado County than No. 7, but it is also greatly dissected and now mainly consists of rolling or hilly country with the tops of the hills about on the same level and with occasional rather extensive flat-topped hills. Rocky Hill, three miles southwest of Glidden and shown on the Columbus profile (figure 3-CD), is a prominent outlier of this terrace so this terrace will be designated the Rocky

Hill Terrace. It is from 340 to 360 feet above sea level or about 150 feet above the river and is 40 to 50 feet lower than the Weimar terrace.

Terrace No. 5 is very strongly and well developed between Cummins Creek and the Colorado River and forms the wide fairly high post oak tableland on which Lorine is located. It is therefore named the Lorine terrace in this county. It has been very slightly eroded in the vicinity of Lorine but on the opposite side of the river it has suffered a certain amount of erosion and trenching, but not so much as the Rocky Hill terrace. The Lorine terrace has an elevation of from 110 to 130 feet above the Colorado River near Lorine or from 300 to 325 feet above the level of the sea. That makes the Lorine terrace (No. 5) about 30 feet lower than No. 6.

Terraces No. 4 and No. 3 are fairly well developed between Lorine and the river, but these as well as the still younger terraces are more typically developed at Columbus and will be more fully described in the discussion of the Columbus profile. Terrace No. 4 lies about 30 feet below No. 5 and is succeeded by No. 3 which drops 20-25 feet below No. 4. There is a fall of 25 feet between No. 3 and No. 2 and of 15 feet between No. 2 and No. 1.

On the southwest side of the river in figure 3-AB there is a 60-foot bluff and terraces No. 1 and No. 2 are necessarily absent. No. 3 and No. 4 are noted only in narrow fairly level places along the flanks of hills facing the river.

In figure 3-CD, which represents an east-west profile section of the Colorado River terraces at Columbus, we find four terraces on the west side of the river and five on the east side.

The highest terrace in this profile is No. 6, or the Rocky Hill terrace. A photograph of the top of Rocky Hill is seen in Plate IV, figure 2. This hill is located about a mile south of the highway three miles west of Glidden and is a gravel covered outlier of this terrace. Its crest is nearly 350 feet above sea level or 175 feet above the Colorado River (average stage) at Columbus. This terrace is well timbered.

The fifth, or Lorine terrace, is crossed by the San Antonio-Houston highway between Glidden and Borden. The 30-foot escarpment between this and the next lower terrace produces a short but fairly steep grade in the highway one-half mile west of Glidden. This fifth terrace is fairly prominent here but has undergone a good deal of dissection. This terrace is 55 feet below the sixth terrace and has an elevation of 275 feet above sea level and 105 feet above the river on the west side. It is well wooded like the last terrace. On the eastern side of the river, in the vicinity of Bernardo it has an elevation of only 260 feet above the sea and 90 feet above the river as compared with 275 feet above the sea and 105 feet above the river on the opposite side. This is probably due to a slight tilting to the southeast.

The town of Glidden is situated on terrace No. 4 and an appropriate name is Glidden terrace. This terrace is only slightly dissected near Glidden and forms a semi-prairie here, there being only scattered clumps of live oak, mesquite and other brush on its flat surface except near the streams. However, it is well wooded for some distance on each side of Skull Creek. This terrace is about 55 feet above the Colorado River and 235 feet above sea level. It is also 30 feet below the Lorine terrace. On the east side of the river the Glidden terrace is very broad and well developed but more dissected than on the west side. It has about the same elevation as on the opposite side of the river or may be slightly lower. The topographic map of the Alleyton-Bernardo region is rather poor and the writer's checks with a hand level are necessarily not very accurate. The major portion of the Glidden terrace in this region is rather thickly wooded. Ramsey, which seems to be located on this terrace, has an elevation of only 225 feet as compared with 234 feet at Glidden.

The third terrace is well developed at Columbus; the town being located on its flat, so it is designated as the Columbus terrace. This terrace extends all the way to the river bank at the Columbus east bridge. It is equally well developed on the opposite side of the river. It lies about 35 feet below the Glidden terrace and it forms the higher ground that is crossed by the highway between Columbus and Alleyton, the highway running close to its inner edge and descending onto the second terrace at Alleyton. The elevation of the Columbus terrace is about 40 feet above the river surface and slightly over 200 feet above sea level.

The second terrace or second bottom of the Colorado River is present but not very well devleoped just across the river from Columbus. It is wider and better developed at Alleyton. Garwood, in the southern part of Colorado County, is located on it so it will be called the Garwood Terrace. It is 15 feet lower than the Columbus Terrace, is 185 feet above sea level and 25 to 30 feet above the river.

The lowest terrace or first bottom of the Colorado River is the present flood plain of the river and is found only eight feet below the Garwood Terrace or second bottom across the east bridge from Columbus. This flood plain is wider south of Alleyton and is typically a densely wooded swamp. It is situated 15 to 20 feet above the river level and 175 feet above sea level at Columbus.

A profile of the river terraces at Altair is shown in figure 3-EF. Terraces 1, 2, 3, 4, and 5 are found on one or the other side of the Colorado River. However, in place of one fairly large Terrace 3 as at Columbus we find two small terraces with a distinct six-foot escarpment between them. The same thing is true of Terrace 4 on the upper minor terrace of which Altair is located. It thus appears that at the time of formation of the Columbus and Glidden terraces there was a more continuous gradual uplift than was the case farther northwest so that two smaller flood plains were developed by the Pleistocene Colorado River in place of one large plain. However, these double terraces are only found on the west side of the river so far as could be ascertained.

The elevations above the river of the terraces on the west side at Altair, beginning with the oldest, are respectively as follows: No. 5: 105 feet; No. 4: 75 and 65 feet; No. 3: 55 and 50 feet; No. 2: 35 feet; No. 1: 20 feet. On the east side No. 4, and apparently No. 3, are somewhat lower than their equivalents on the west side, probably due to a slight tilting to the southeast. No. 1 is present on the east side but absent on the west.

At Garwood only the three lower terraces are found. However, there is no prominent escarpment between the second and third terraces but a rather gradual rise. Garwood is situated on the second terrace which is well developed in this vicinity, having a width of from one to three miles. The first terrace or present flood plain is also about a mile wide on the east side of the river but is not present on the west side in this vicinity, so that one gains the impression in going toward Garwood from the west that there are no river terraces at Garwood.

On the east side of the river the second terrace is noted as a higher area extending from one-half mile south of Slutter to Calhoun and Englehart.

The third or Columbus terrace is better defined on the east side, the village of Matthews (elevation 172 feet above sea level), being located on this terrace. The first terrace is developed along Caney Creek and Eagle Lake which occupy the former channel of the Colorado River.

In addition to the wide river terraces equivalent terraces follow up the larger tributaries of the Colorado and Navidad, being especially well marked in the northwestern part of the county. The various forks of Harvey and Skull creeks, especially in their upper reaches, have two well developed terraces which together reach a width of a mile in places. About one and one-half miles northeast of Oakland an old lake deposit covering several acres is found near the headwaters of a small stream flowing southwest into the Navidad River. However, Skull and Sandies creeks are the only large streams that flow across the flat Upper Lissie terraces.

DRAINAGE

The drainage of Colorado County has been discussed in connection with the various physiographic divisions of the county. However, there are some general features and changes in drainage which will be mentioned here.

Colorado County is drained by three independent river systems: (1) the Colorado System; (2) the San Bernard System; and (3) the Navidad System.

The Colorado is the principal drainage system and the three largest tributaries of the Colorado River in this county are: Cummins, Skull and Harvey creeks, named in the order of their relative size.

The general course of the Colorado River from the Fayette County line to Columbus is almost east while south of Columbus it is almost south. The river thus makes a distinct bend toward the northeast. This bend is the most distinct large bend south of the Central Mineral Region. The course of the river is also strongly meandering, the largest of these minor bends or meanders being located northeast of Columbus. This meander is only a mile across and it is several miles around it.

There is very good evidence that the Colorado River below Alleyton has migrated to the west of its former channel a maximum distance of four miles in Colorado County. The broad, low, wooded bottom of the river extending from Alleyton to Ramsey and becoming widest at Ramsey is evidence of the first and smaller migration. However, on the opposite side of the river southwest of Ramsey is another distinct widening of the bottom and a small ox-bow lake which shows the river was rather recently even farther west here than at present.

The main change in the course of the Colorado River has occurred near Eagle Lake. From Slutter to Eagle Lake the river valley extends due east while the course of the river channel is almost south. Also the 150-foot contour which crosses the river between Altair and Slutter swings around Eagle Lake and follows Little Caney Creek south from Eagle Lake almost to its junction with the Colorado River. There is a distinct channel, much too large for the size of the stream, which follows Little Caney south from Eagle Lake and this and Eagle Lake itself were doubtless the bed of the Colorado River in late Pleistocene or early Recent time. Also river clams (Unio) and bones apparently of bisons were found in the side of an irrigation ditch in the old bed of the river between Matthews and Calhoun. The probable former courses of the river are shown by dotted blue lines on the geologic map in the pocket. The river bottom on the east side near Garwood and south to Wharton is quite wide and there is a very slight divide between the banks of the Colorado River and those of Old Caney Creek in the vicinity of its present source near Wharton. Also the head of Old Caney Creek is less than two miles east of the present channel of the Colorado River at Wharton. The bed of Old Caney is far too broad for the present stream and the stream resembles a bayou more than a creek in appearance. It therefore seems almost certain that the bed of Old Caney which parallels the Colorado River a few miles east all the way to the Gulf was in fairly recent times the channel of the Colorado River. Little Caney, which is the outlet of Eagle Lake, and Eagle Lake itself are thought to have been connected with Old Caney when the Colorado River occupied that channel. The break that was made by the Colorado River from its old channel probably occurred in Colorado County between Eagle Lake and Altair.

The San Bernard and Navidad rivers which form part of the northeast and west boundaries of Colorado County are only small streams in this county. The several branches of Sandies Creek in Colorado County unite and flow south into the Navidad River in Jackson County. Mustang Creek, which heads only two miles west of the present Colorado River channel at Garwood and has been previously described in connection with the topography of the Upper Lissie Prairie, is also a branch of the Navidad River, the divide in this case being surprisingly near the present Colorado River.

Floods are not uncommon in the Colorado River and all the other rivers and larger creeks in this county. One of the greatest floods occurred in May, 1913, at which time the water overflowed the third terrace and was a few feet deep in the streets of Columbus.

GEOLOGY

All the formations of Colorado County are sedimentary and were deposited in Tertiary and Quaternary times. No igneous intrusions or lava flows of any kind are found at or near the surface in Colorado County, although there is a bed of bentonite-like clay in the Quaternary which may be a fine volcanic ash deposited under water.

Considerable difficulty was experienced in mapping and differentiating formations both on account of the extreme paucity of good exposures and on account of a capping of terrace material in many places.

TERTIARY SYSTEM

The oldest rocks exposed on the surface in Colorado County were deposited in the latter part of the Tertiary period, the Upper Miocene and Pliocene epochs. However, Upper Eocene and Oligocene beds have been penetrated by the drill in this county and also just across the line in Austin and Lavaca counties. A columnar section of the formations in Colorado County is shown in figure 4.

FORMATIONS NOT EXPOSED AT THE SURFACE

EOCENE

It is probable that the Fayette (Jackson) and possibly the upper part of the Yegua (Claiborne) Eocene have been penetrated in the Kiser No. 1 well of the Columbus Bernardo Oil Company, near Ramsey and in the Laas No. 1 of the Lavaca County Oil Company, in Lavaca County near Shimek, each of these wells having been drilled to 3,000 feet or over. However, the Columbus-Bernardo Oil Company refused to submit any samples or their well log for study and only a few of the samples from this well were casually seen by the writer. The oldest formation that has certainly been penetrated in the Laas well, as checked by a microscopic examination of samples, is the Frio or Upper Jackson Eocene. It is possible that the Fayette (Jackson) sandstone is penetrated at 2720 feet.

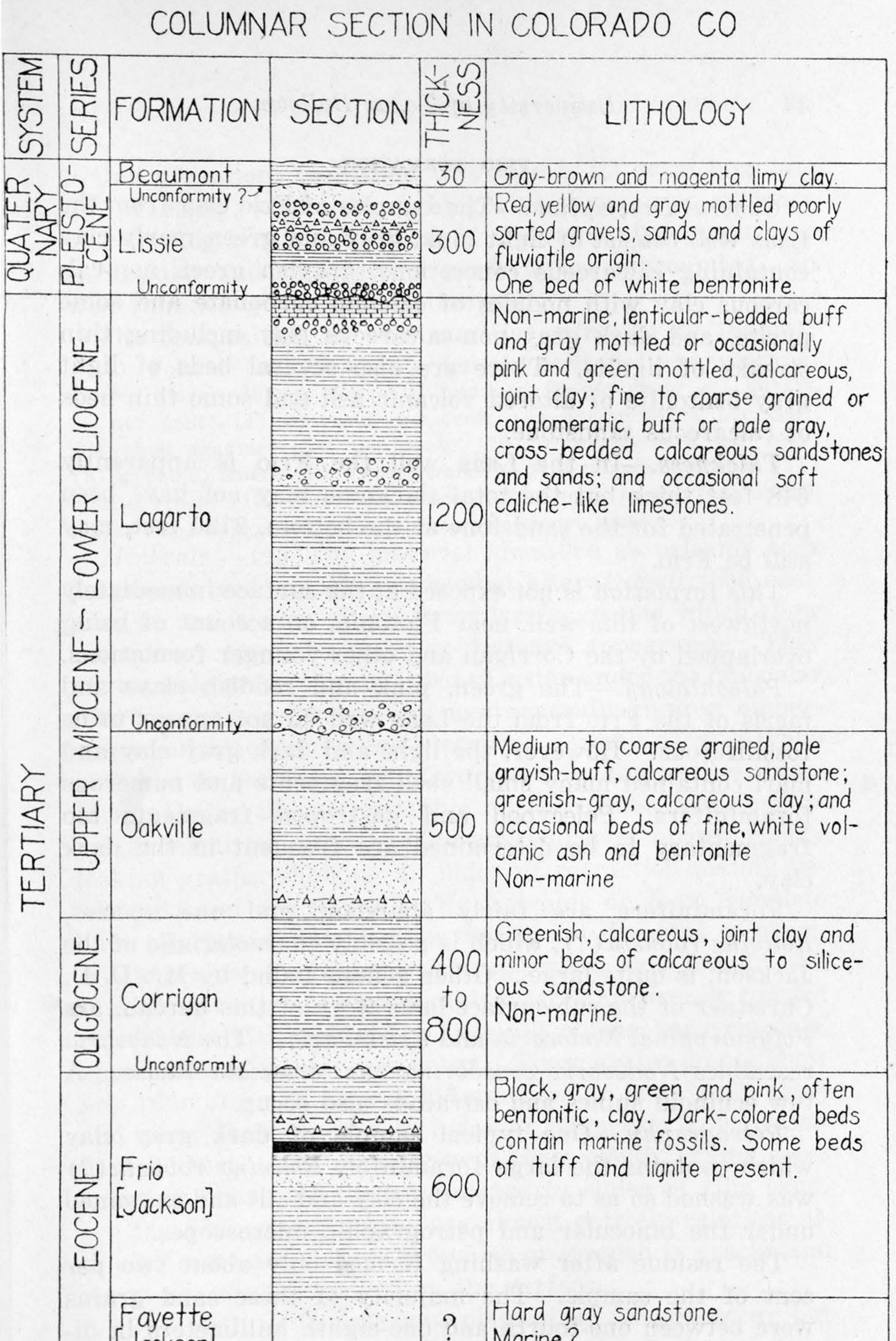

Fig. 4. Columnar section of the geologic formations in Colorado County. The formations thicken toward the southeast, the thickness given being an approach to the maximum for each formation in this county.

FRIO FORMATION

General Description.—The samples of Frio clay from the Laas well consist of light pink, gray and green marly clay containing calcareous concretions, grayish green non-calcareous clay with nodules of calcium carbonate and some pyrite, and dark gray non-calcareous clay including thin streaks of lignite. There are also several beds of light gray bentonite or altered volcanic ash and some thin beds of calcareous sandstone.

Thickness.—In the Laas well the Frio is apparently 648 feet thick but the total thickness may not have been penetrated for the sandstone at the bottom, 2720 feet, may still be Frio.

This formation is not exposed at the surface immediately northwest of this well, near Flatonia, on account of being overlapped by the Corrigan and other younger formations.

Paleontology.—The green, pink and reddish clays and marls of the Frio from the Laas well do not appear to be fossiliferous. However. the light and dark gray clay and marl contained many small shell fragments and numerous foraminifera. Pelecypod and gastropod fragments too fragmentary to be determined are frequent in the dark clay.

Foraminifera are fairly abundant and one species, *Bolivina robusta*(?), which is possibly characteristic of the Jackson, is quite large. Other genera found by Mr. D. D. Christner of the sub-surface laboratory of this bureau, are *Polymorphina, Nodosaria* and *Cristellaria.* The *Nodosaria* resembles *Nodosaria consobrina* var. *emaciata* Reuss. A few echinoid spines and ostracods also occur.

Petrography.—One typical sample of dark gray clay which contains the large foraminfer, *Bolivina robusta*(?) was washed so as to remove the clay and silt and examined under the binocular and petrographic microscopes.

The residue after washing formed only about two per cent of the sample. The majority of these sand grains were between one-fourth and one-eighth millimeters in diameter. About 20 per cent, including many foraminfera and shell fragments, were over one-half millimeter.

One prominent feature of this sand is its great angularity, probably two-thirds of the grains showing no evidence of rounding whatever. Most of the remaining grains are subangular and not over one per cent are subrounded. No well rounded grains were observed.

The composition of this sand is estimated as follows: (1) Volcanic rock fragments (mainly devitrified and somewhat altered glass), 35 per cent; (2) feldspar, 25 per cent; (3) quartz, 25 per cent; (4) chert, 5 per cent; (5) aragonite, 3 per cent; (6) shell fragments, 4 per cent; (7) foraminifera, 3 per cent; (8) gypsum, trace; (9) pyrite, trace; (10) tourmaline, trace; (11) biotite, trace; (12) muscovite, trace; (13) zircon, trace; (14) spinel, trace; (15) magnetite, very rare; chalcedony, trace.

Minerals.—(1) The material identified as volcanic rock fragments and probably somewhat altered devitrified obsidian occurs in very sharp irregular fragments which show a tendency toward a flaky or flattened appearance. They have a pale gray color and greasy luster under the binocular microscope in reflected light and generally contain numerous small black irregular inclusions. Some show a wavy streaked or banded appearance probably due to flow structure. Under the petrographic microscope in plane polarized transmitted light they appear as grayish brown, cloudy looking grains, showing an index of refraction mainly below 1.54 and are either partly isotropic or show complete hazy aggregatal polarization that is not like that of chert. A few grains of completely isotropic glass were found. All these fragments are considerably altered apparently toward leverrierite although a few included oblong hazy crystals, apparently of felspar, are noted. These grains do not show any rounding and have a different luster from gray chert and many show too low an index of refraction to be classified as chert. The abundance of these cloudy grains gives a rather characteristic appearance to slides of this sand.

(2) The quartz grains are almost entirely colorless although some are stained brownish or grayish in cracks and many are slightly etched on the surface.

(3) Both orthoclase and plagioclase felspar occur but no microcline was seen, although microcline is the principal felspar present in the Miocene-Pliocene rocks in this region.

In the sample of Frio dark gray clay most of the orthoclase is considerably altered and gives a brownish cloudy appearance which often resembles the volcanic rock fragments but from which it is easily distinguished under crossed nicols when the cleavage does not show.

The plagioclase felspar often shows twinning but many grains do not. The untwinned grains can be determined by their indices of refraction and cleavage. The plagioclase as determined by index of refraction varies from albite to andesine with albite and albite-oligoclase commonest. The plagioclase felspars seem to be on the whole less altered and stained than the orthoclase. Possibly orthoclase is slightly more abundant than plagioclase. No pink felspar of either type was seen. This may be due to the abundant organic matter present in this clay, but probably much of the felspar is of the glassy volcanic type rather than the pearly, often pink, plutonic type.

(4) The larger chert grains are reddish in color and look like fragments of irregularly deposited and pitted incrustations of chalcedonic material. Most of the smaller chert grains are pale gray or almost colorless and translucent in transmitted light. They show aggregated polarization which is not hazy like the volcanic fragments.

(5) Gypsum occurs in platy and elongated, transparent, fresh looking grains.

(6) Aragonite in considerable amounts is a peculiarity of this sample. It occurs in bright, glittering, transparent, generally slender prisms or in groups of semi-fibrous parallel prisms. The basal cleavage shows up rather prominently in many crystals. A few prisms are stained brown along cleavage cracks.

(7) Chalcedony is found in elongated bluish-white grains showing wavy extinction under crossed nicols.

(8) Pyrite occurs sparingly both in tiny cubes and in well-rounded tiny concretions having drusy surfaces or as roundish groups of very minute oolite-like concretions.

(9) Tourmaline is seen occasionally in short prismatic grains having a yellow to deep brown pleochroism.

The other minerals are rather infrequent and have no peculiarities of their own in this sample.

The foraminifera and shell fragments make up about five per cent or more of the sample.

Other samples of pale green clay and magenta colored clay (Laas No. 1), were also examined in a similar manner to the dark gray clay described above. The sand in the green and pink clays formed about five per cent or possibly more of the sample. However, about one-fourth of this sand consisted of small lime nodules ranging from two millimeters to one-fourth millimeter in diameter.

About 30 per cent of the washed material or sand is composed of grains over one-half millimeter in diameter. However, these coarser grains consist of about half lime nodules containing numerous small pyrite cubes and half coarse-grained, whitish, calcareous sandstone fragments. There are a few clear or yellowish quartz grains and pink and yellow chert grains over one-half millimeter in diameter.

Most of the sand is between one-fourth and one-eighth millimeter, though about 15 per cent is below one-eighth millimeter. The sorting is somewhat better than in the black clay, although fine sand was the most abundant separate in both. The grains are almost entirely angular as in the preceding sample.

The mineral composition of the sand from this pink and green clay is similar in general to that in the dark gray clay except that cubes of pyrite are much more abundant (probably 10 per cent). Only a few imperfect aragonite prisms were seen and a few elongated or wedge-shaped angular glass fragments showing flow-structure and bubbles like perlite were noted. Also a few glauconite and chlorite grains and many grains of pink or reddish chert and possibly some pinkish rhyolite or trachyte fragments were found.

These clays also differ from the above sample very strikingly in the absence of foraminifera and other organic fragments and are probably of fresh water origin while the dark clays are marine.

ORIGIN

It is probable that the Frio formation was deposited near an old and probably flat shore line at a time when active volcanoes were present nearby. This formation shows an apparent alternation between fresh and salt water conditions and may be partly if not largely of river delta origin. The lignite streaks in the dark gray clay and absence of fossils in the green and pink clays point to a probable fresh water origin for these portions. The marine fossils, on the other hand, show that part of this formation was deposited under marine conditions.

OLIGOCENE

CORRIGAN FORMATION

Rocks of Corrigan (Oligocene) age like the Eocene are found in this region only in deep wells.

M. I. Goldman[1] has made a very detailed petrographic analysis of surface samples of the Catahoula (Corrigan) sandstone from Trinity County, Texas, so no attempt will be made to describe the formation except that which was found in a well in the Colorado County region.

General Description.—The Corrigan or Catahoula formation underlying Colorado County contains a large amount of clay, far more than sandstone. This is shown by the samples from the Texas Company's Schaffner No. 1. which is located a few miles across the Colorado County line at Red Hill in Austin County. The location of this well is shown on the geologic map. The samples described showed a pale green non-calcareous clay containing lime nodules to be the principal lithologic type.

The log of the Texas Company's Red Hill well (Schaffner No. 1) is shown on page 155 of this report. Miss Hedwig Kniker has drawn the contact between the Oligocene and the overlying Miocene-Pliocene at 2147 feet on the basis of lithology since no fossils of stratigraphic value were pres-

[1]Goldman, M. I., Petrographic Evidence on the Origin of the Catahoula Sandstone of Texas. Am. Jour. Sci. 4, V. 39, pp. 261-287.

ent. The principal rock type is a light green, non-calcareous clay which when washed left a residue of more or less sand and calcareous concretions. A few beds of sand and gray clay were also present and a few fragments of lignite were noted.

Thickness.—According to Miss Kniker's opinion, with which the writer agrees, there was 830 feet of Corrigan and the base had not been reached in the Red Hill well. However, as nearly as could be determined by the log, there were only about 300 feet or less of this formation present in the Laas well in Lavaca County and only a short distance from the Colorado line.

Paleontology.—The only fossils that have been reported from the Oligocene in this region were secondarily introduced foraminifera of the genera *Globigerina, Textularia, Cristellaria* and *Anomalina,* an ostracod, and a Chara fruit case. Even these are very rare. These were reported from the Red Hill (Schaffner No. 1) well in Austin County by Miss Kniker.

Petrography.—Several samples of Corrigan clay from this well were examined by the author. These had a close resemblance to one another. The description of a typical sample from 2390 to 2395 feet follows:

The sample consists of a stiff, pale yellow-green, almost non-calcareous clay containing a few small calcareous concretions. Part of the sample consists of a pale gray rather pure loose sand. The sand both in the clay and sand portions is mainly subangular.

The mineral composition of the washed material from the clay and sand is estimated as follows:

(1) Quartz, 68 per cent; (2) felspar, 14 per cent; (3) chert, 12 per cent; (4) magnetite, 2 per cent; (5) calcite (concretionary), 3 per cent; (6) pyrite, trace; (7) gypsum, 1 per cent; (8) tourmaline, trace; (9) zircon, trace; (10) yellow dolomite rhombs, trace.

Most of the felspar in this sand is somewhat altered orthoclase. Plagioclase is common and generally fresh. Microcline is rare.

No fossils of any kind were noted.

The scarcity of microcline may be a distinguishing characteristic, by means of which the Corrigan may be told from the overlying Oakville.

ORIGIN

The Corrigan is apparently mainly of continental origin and the presence of Chara fruit show that at least part of it was deposited in fresh water. Also other fresh water fossils such as nuts, leaves and stems of land plants are frequently noted in the Catahoula (Corrigan) sandstone in Trinity County and other places as noted by Goldman[1] and others.

The writer believes that most of the Corrigan underlying the Colorado County region was formed in a large river delta which was probably shut off from the open sea by islands or bars. Additions were probably made to this delta by the wind.

Goldman's evidence on the origin of the Catahoula sandstone from Trinity County which he studied, is in substance as follows:

(1) The sizing indicates a beach or eolian origin.

(2) The lower limit of rounding is like æolian sand while the proportion of rounded grains resembles sea sand.

(3) The ratio of felspar to quartz is taken to indicate that the source of the sand was nearby.

(4) The ratio of heavy minerals to light minerals suggests dune sand origin.

(5) The species of heavy minerals and their ratios to each other points to probable aridity.

(6) The source is thought to be an acid igneous rock.

(7) The absence of bedding points to their rapid accumulation by a current of wind or water and the arrangement of fossils suggests that the sand was brought into a body of quiet water by the wind largely.

(8) The character of the clay galls supports the belief that the material is derived from the washing out of aeolian sand.

(9) The character of the fossils indicates a tropical climate.

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[1]Goldman, M. I., *Op. cit.*, pp. 261-262.

FORMATIONS EXPOSED IN COLORADO COUNTY

UPPER MICOCENE—LOWER PLIOCENE

The oldest rocks that are exposed on the surface in Colorado County are either of Upper Miocene or Lower Pliocene age, or else the period of their deposition extended from Middle Miocene to Middle Pliocene. Dumble[1] has divided this belt of sedimentary deposits west of the Brazos River into three formations, the Oakville, Lapara and Lagarto. The Oakville was placed in the Upper Miocene on the basis of Leidy's and Cope's determination of the fossils from it.

The Lapara fossils were pronounced by Cope to be of Pliocene age and equivalent to the Blanco Pliocene of the Llano Estacado.

Dumble considers the Lagarto, which overlies the Lapara, as Pliocene also. However, neither he nor any other writers, so far as the present writer has been able to ascertain, have reported any fossils in the Lagarto.

During his field work in Colorado County the present writer discovered, in what is almost certainly Lagarto sandstone, teeth of the horse *Protohippus perditus*. This species is also found in the Oakville. Osborne[2] gives the range of *Protohippus perditus* as Upper Miocene and Lower Pliocene (Procamelus-Hipparion zone) so that it is possible either that the Oakville, Lapara and Lagarto of Dumble was deposited in Upper Miocene or Lower Pliocene or that the Lower part (or Oakville) was deposited in Upper Miocene and the upper part in the Lower Pliocene. This will be discussed more fully under the paleontology of the Lagarto formation.

A careful petrographic study of the lower, middle and upper portions of the Miocene-Pliocene rocks in Colorado and Fayette counties has revealed a great similarity between all three portions especially in the sands and sand-

[1]Dumble, E. T., The Cenozoic Deposits of Texas, Jour. of Geol., V. 2, No. 6, pp. 555-560.

[2]Osborne, H. F., Equidae of the Oligocene, Miocene and Pliocene of North America, Amer. Mus. Nat. Hist. Mus. N. S., V. 2 pt., p. 129.

stones. However. the lower part, or Oakville. is predominantly sandy and the upper part, or Lapara-Lagarto, consists mainly of clay. There is also an unconformity, at least in places, between the Oakville and the upper clays and sands. Although the same species of three-toed horse is apparently found both in the Oakville and Lagarto, the future discovery of a larger number of fossils from the Lagarto may reveal a certain amount of difference between the two faunas. A considerable period of time must have been taken to deposit such thick formations. It is therefore considered advisable to divide the Upper Miocene-Lower Pliocene rocks into the Oakville and Lagarto formations. The Lapara is not considered to be of formational rank, although it may be sufficiently distinctive to be classed as a member of the Lagarto. This will be discussed more fully later. These two formations together are considered to be equivalent in age to the larger part of the Fleming Clays of East Texas, although it is possible that the lowest Fleming is somewhat older than the lowest Oakville. (See Univ. of Tex. Bull. No. 1869, pp. 224, 230, and 237; also U. S. G. S. Wat. Sup. Paper 335, pp. 72-73.)

OAKVILLE FORMATION

The Oakville is not exposed on the surface anywhere in Colorado County, but is apparently encountered in all wells over 1500 feet in depth. However, this formation is well exposed in Fayette County and the writer has studied the surface exposures of this formation at La Grange Bluff and between Flatonia and Schulenburg in Fayette County.

General Description.—In the exposures studied the Oakville consists mainly of a very friable or poorly cemented, massive-bedded, or cross-bedded, grayish-white to pale yellowish-gray, coarse to fine grained sandstone. The cement is composed of glassy, crystalline calcite, which usually constitutes over 25 per cent of the sandstone. The grains are largely subangular, although sharply angular grains are quite abundant especially in the finer separates. A few grains are subrounded to rounded, but these form less than one per cent of the total. More or less eroded secondary shell fragments are very abundant, especially in certain portions, and a few recognizable Cretaceous oysters are found. In places the shell fragments are so abundant that it may be called a coquina sandstone. More or less eroded bone fragments are also quite common. This sandstone ought to be easily distinguished from the underlying Catahoula sandstone on the basis of rounded grain percentage if the Catahoula sandstone that Goldman studied is typical of that formation all over the Texas coastal plain.

Less prominent and thinner beds of greenish, calcareous clay with abundant calcareous concretions and pale, greenish-white to pale gray, arenaceous, calcareous clay also occur. The lime concretions often reach a diameter of over an inch and a few elongated concretions three inches long were noted. Some beds of sandy clay containing large calcareous concretions from La Grange Bluff were studied in detail. This clay has the peculiar property of rapidly slaking and breaking down into a soft, doughy mass when moistened with water. The fine sand is easily separated from the clay by decanting off the suspended clay after a piece of the hard, dry, sandy clay has been left in water for two or three minutes and the water then stirred up. This property of rapidly slaking in water has been considered as characteristic of bentonite, a completely hydrated practically colloidal volcanic ash or dust. The sand grains were very largely between one-fourth and one-eighth millimeter in diameter and were mainly angular, though many subangular grains occur. The largest grains were only four-tenths of a millimeter in diameter. Some aggregates of sand grains cemented with calcite also occur.

Oakville in Wells.—Unlike its surface outcrops the Oakville formation underlying Colorado County, especially in the southeastern part which is more distant from the Oakville outcrop, becomes predominantly argillaceous. Samples from the Texas Company's Schaffner No. 1 well mentioned previously, show a creamy to greenish-gray, strongly calcareous, often bentonitic, stiff joint clay to be the principal lithologic type. This clay contains numerous small calcareous concretions.

A description of a sample of this clay from 1790 feet made by the writer follows:

The sample consists of a creamy-gray to pale greenish-gray, calcareous, bentónitic, joint clay. About five per cent of material is left after the clay has been washed out. This washed material is composed mainly of white calcareous concretions up to two millimeters in diameter. The sand grains that are present are mainly subangular in outline and most of them are below one-fourth millimeter in diameter.

The composition of the total washed material is estimated as follows:

(1) Calcareous concretions, 65 per cent; (2) quartz, 15 per cent; (3) felspar, 10 per cent; (4) chert, 8 per cent; (5) gypsum, 2 per cent; (6) glauconite, trace; (7) magnetite, trace; (8) foraminifera (Globigerina and Cristellaria), trace.

All three varieties of felspar are present in the above sample and probably one-third of the felspar is microcline. Plagioclase is the least abundant felspar. Most of the chert is gray but some pinkish and yellow grains and some greenish chloritic, cherty grains (probably altered rhyolite or andesite) occur.

Thickness and Dip.—The thickness of the Oakville varies from 495 feet in western Colorado County to 550 feet a few miles across the eastern boundary so nearly as can be told from well logs and well descriptions.

The dip is considered to be about the same as that of the Lagarto, but this is uncertain due to irregularities of bedding. The dip was seen in only a few places in Fayette County.

Paleontology.—The fossils found in the Oakville consist of numerous more or less eroded secondary pelecypod and gastropod shells or shell fragments derived mainly from the Cretaceous, numerous foraminifera, largely, if not entirely, of secondary origin, a few Chara stems, rare diatoms, and occasional more or less well preserved vertebrate remains. Many of the vertebrates have been collected by

Dumble and a discussion of the Oakville fauna is found in his "Cenozoic Deposits of Texas" and other papers on the Tertiary geology of Texas.

Cameralucida drawings of most of the common foraminifera and other microscopic fossils of the Oakville are found in figure 5. The genera of foraminifera noted are Globigerina, Textularia, Anomalina, Nodosaria, and Cristellaria, all probably from the Cretaceous. A few tiny spore-like bodies were also noted in the Oakville.

The single disc-shaped diatom noted is apparently a marine species. It is very thin shelled and was probably broken during the washing process. It is thought to have lived in Oakville time because such a thin shelled organism could hardly have been transported far.

In figure 5, Nos. 4 and 7, have been noted only in the Oakville, but a more careful study might reveal their presence in the Lagarto also.

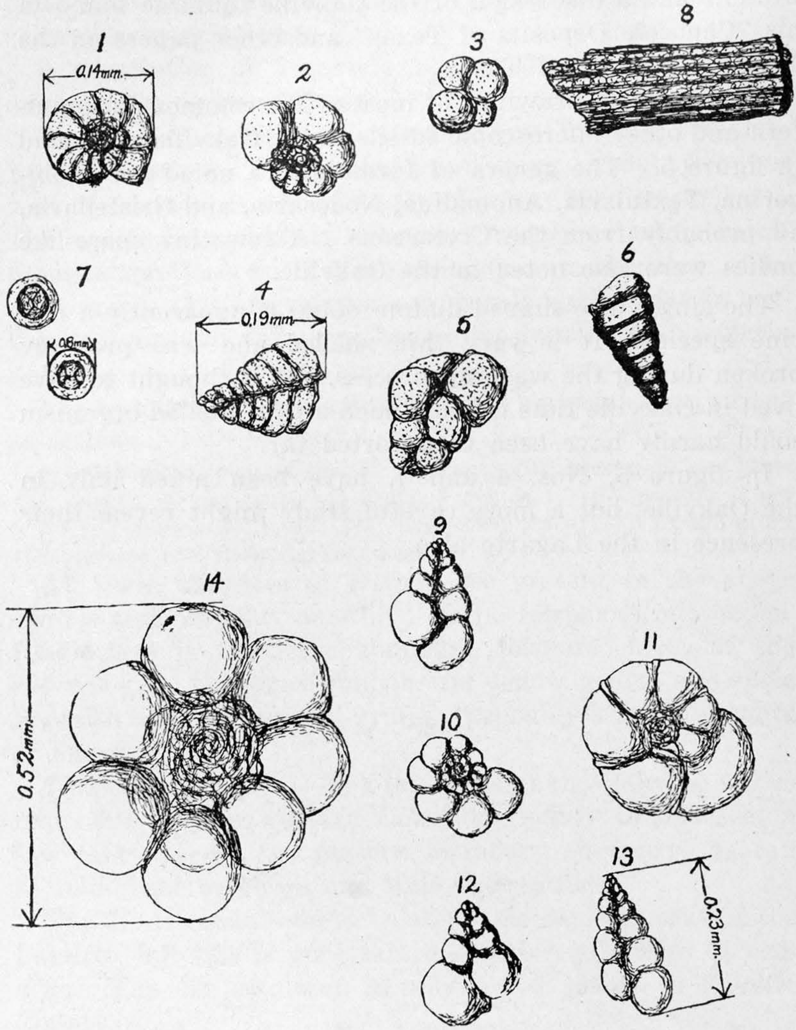

Fig. 5. Camera lucida drawings of common microscopic fossils of the Oakville and Lagarto formations. (Most of the foraminifera are probably secondary.) Magnified approximately 75X. 1. Anomalina (Oakville); 2 and 3. Globigerina (Oakville); 4. Textularia sagittula? (Oakville); 5. Textularia globulosa? (Oakville); 6. Nodosaria sp. (Oakville and Lagarto); 7. Spores? (Oakville); 8. Chara stem (Oakville and Lagarto); 9, 12 and 13. Textularia cf. globulosa (varieties?) (Lagarto); 10. Globigerina (Lagarto); 11. Pulvinulina (Lagarto); 14. Globigerina (Lagarto).

METHOD OF STUDY OF SEDIMENTARY SAMPLES

A brief description of the methods followed in preparation for study and the study of the sedimentary rocks described in this paper is given below. This method was followed not only for the Oakville, but for all the other samples described. This method is rather inexact and faulty, but it is thought that a much clearer idea of the composition of the formations described can be gained by a rather hurried study of this kind than where no attempt at a detailed microscopic and petrographic study is made.

All the consolidated rocks studied in connection with this report owed their lithifaction to the presence of considerable calcareous cement. Only three samples were collected which were well enough cemented to have thin sections made of them and these three were studied in thin section also.

Where the specimen was lithified two parts were generally prepared for study: (1) the cement was dissolved with diluted hydrochloric acid leaving the insoluble sand grains; (2) the specimen was crushed either with the fingers (when possible) or a pestle. The crushing of the sandstone was usually easily accomplished on account of imperfect cementation and observations showed that this rarely destroyed the original shape of the grains because the cement is much more easily broken than the grains themselves. Also, when the specimen is treated with acid all the calcareous organic remains are destroyed so that an incorrect idea of the composition is obtained from a study of sandstones, which have been separated into their grains by acid. However, in the harder specimens it was considered desirable to study the acid treated material in order to get a correct idea of the shape and mineral composition of the sand grains.

Where the sample was a clay or sandy clay or a sandstone or conglomerate with argillaceous cement the grains could be separated by soaking in water and breaking up with the fingers. After the samples had been separated into their constituents the clay and very fine silt was decanted off. A part of this fine material was saved for study in several samples by placing a little of the murky water in a watch glass to settle and the water evaporated. However, the principal study even in the case of clays was done on the sand and gravel or washed material. After the sand and gravel was clean it was dried and passed through a nest of seives having diameters of eight millimeters, four millimeters, two millimeters, one millimeter, one-half millimeter, one-fourth millimeter, and one-eighth millimeter, according to Dr. Udden's system used in the sub-surface laboratory of this bureau. In this way all the sand of the same approximate size can be studied separately. This is necessary for microscopic study for the large grains hold up the cover glass on a slide so as to give a very unsatisfactory mount. Also the sorting of the sand is thus observed.

Since a study of this kind is necessarily only approximate in its results, unless an enormous amount of time is spent, the percentage of the total sand and gravel present in each of the sieve separates was estimated by comparing its volume with the volume of each of other separates from a given sample.

The percentage of clay present was obtained by measuring out about 10 to 30 cubic centimeters in a graduated tube, washing out the clay and again measuring the dried sand and gravel residue, the loss being considered clay. This is only an approximation but will come out within five per cent or less of the correct amount where there is a considerable percentage of coarse and fine material both in the same sample. Where both gravel and sand are present they have to be mixed so that the spaces between pebbles will be filled up, otherwise too large a percentage of sand and gravel is obtained. Of course a certain amount of space is present between the sand grains that originally would have been filled with clay and in many specimens the clay washed out was saved, dried and measured separately in the graduated tube so that the writer was able to estimate the clay percentages more closely. This is a quick method but weighing of the samples before and after washing is more accurate.

The calcium carbonate percentages, with the exception of fifteen, were obtained by measuring the crushed sand and clay in a graduated tube, dissolving out the calcite or aragonite and measuring again. Fifteen were submitted to the chemical division of this bureau for accurate calcium carbonate determinations and these were not over 10 per cent off the writer's previous rough volumetric determinations for fairly pure sandstones and sands, but this method proved rather unsatisfactory for clays, both on account of the difficulty in washing the acid treated clay and in drying it. A better method for all these calcium carbonate percentages is to weigh the sample before and after treating with dilute hydrochloric acid and take the difference as calcium carbonate. This is the method used by Dr. George D. Louderback of the University of California for calculating lime percentages. In the table of calcium carbonate percentages, Table 3, on page 90, of this report those checked by accurate chemical analyses are indicated by an asterisk.

The sand and gravel separates were studied individually both for mineral and organic content. The gravel pebbles (over one millimeter in diameter) were studied with the hand lens and doubtful pebbles were crushed and their fragments studied under the petrographic microscope as described below for the sands. Where gravel was an important item in the composition of a sample the pebbles of each type were counted and the percentage of each thus determined.

The sands were studied both under the binocular microscope in reflected light and petrographic microscope in transmitted polarized light. The writer was generally able to tell chert from quartz and to identify a certain amount of the felspar with the binocular microscope. He could usually identify shell fragments, calcareous, manganiferous and ferruginous noddules, magnetite and mica flakes more quickly under the binocular than the petrographic instrument. However, it was necessary to immerse most of the sands in oils of known indices of refraction in order to get much of an idea of the mineral composition. The heavy minerals were also separated from the light in the fine sand by means of bromoform and the heavy minerals thus obtained studied separately. The percentages of various minerals and organisms in each sample which are shown in Table 4, facing page 90, are estimated by comparing the number of grains of one mineral with those of another in various parts of a slide or of several slides in some cases. Most of the slides made contained several hundred grains so that they ought to be fairly representative of each separate. These slides were also examined carefully for the rarer minerals and for foraminifera and other microscopic organisms. An attempt has been made to represent the mineral and organic composition of each specimen so that by looking up a given sample in the table a fairly accurate idea of it can be obtained and an accurate idea of a formation by studying several of the type rocks from it. An effort has been made to include a sample of each more or less distinct lithologic type found in Colorado County.

*Petrography of the Oakville.**—Two samples of Oakville both from near the middle of La Grange Bluff, one-half mile south of La Grange, Fayette County, were the only samples of Oakville of which a petrographic study was made. This station is given the symbol of To 1 in Tables 1, 2, 3, and 4. The samples are from the basal part of the Oakville.

To 1 No. 1 (sandstone) is a medium to coarse, pale yellowish-gray to whitish friable sandstone containing abundant worn shell fragments.

To 1 No. 2 (sandy clay) is a fine, whitish arenaceous, calcareous clay. The clay in this sample slakes like bentonite.

Sorting.—The details of sorting in the two Oakville samples described above can be obtained by referring to Table 2.

In the sandstone sample over half the sand grains are between one and one-half millimeters while 30 per cent are between one-half and one-fourth millimeter. One large shell fragment is between four and two millimeters and in

*Note: In the text following and in the tables the following abbreviations are sometimes used: To=Tertiary Oakville; Tlp=Tertiary Lapara; Tlg=Tertiary Lagarto; Ql=Quaternary Lissie; Qb=Quaternary Beaumont.

fact all the grains above one millimeter are shell fragments. This sorting seems to be intermediate in character between Thoulet's examples of typical shore sediments from the Gulf of Lyon and sediment from the Rhone delta and is not unlike Sudry's sample of a delta in a lagoon, except that there is only a very small amount of clay present in this Oakville sample. The next finer separate to the maximum is the second largest separate, which has been stated by some authorities on sedimentation to be characteristic of current action.

In the sample of sandy (bentonite-like) clay that occurs interbedded with the sandstone we find that clay constitutes the maximum separate while sand between one-fourth and one-eighth millimeter is next most prominent. Two maxima are thus found in this sample with the clay maximum much the larger. The sorting of this sample resembles most closely the finer lagoonal sediment reported by Sudry from the Lagoon of Thau. The types of sediments that have been referred to above have been plotted by Goldman[1] and references to their original sources are found in his paper.

Shape of Grains.—The sand grains in the Oakville samples studied have been characteristically subangular in the sandstone and rather sharply angular in the sandy clay.

Calcium Carbonate Content.—The calcium carbonate content of the Oakville and other samples studied is found in Table 3. The Oakville sandstone was found to contain about 40 per cent of $CaCO_3$ of which probably 15 per cent is shell fragments and other calcareous organic material. This leaves about 25 per cent of $CaCO_3$ for the cementing material of the rock. A petrographic examination of this cement has shown it to be largely calcite although a very small amount of dolomite is also present.

The Oakville clay (bentonite ?) To 1 No. 2, was estimated as containing 35 per cent of calcium carbonate of which 12 per cent was in the washed sand and 22 per cent in the clay.

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[1]Goldman, M. I. The Petrography and Genesis of the Sediments of the Upper Cretaceous of Maryland, Md. Geol. Surv., Up. Cret., p. 170.

About 15 per cent or possibly more of the calcite in the sand consisted of small foraminifera and other calcareous organic material.

Composition of the Sands.—The quantitative mineral and organic composition of the Oakville samples is found in Table 4, together with that of the other samples studied under the petrographic microscope. The percentages given here are only estimated but are thought to be fairly close approximations.

Minerals of the Oakville.—The minerals described here are very similar to the same minerals found in the Lagarto and their description in this place will serve for the minerals in both formations, with the exceptions noted under "Comparison of the Oakville and Lagarto" on page 92.

For convenience in treatment the minerals of the Oakville will be divided into "light" and "heavy" minerals. However, about 98 per cent of the volume of Oakville rocks studied is composed of five of the "light" minerals. These five very abundant minerals are quartz, clay, calcite, chert and felspar and they occur about in the order named. The other "light minerals" noted are quartzite, chalcedony, leverrierite, gypsum, shale and slate, dolomite and volcanic glass. Clay, shale and slate, volcanic glass and quartzite are not single minerals but are classed here for convenience.

The "heavy minerals" do not often make up over one per cent of the volume of a sample. They occur in approximately the following order: magnetite, zircon, limonite, biotite, muscovite, ilmenite, barite, garnet, epidote, tourmaline, pyrite, hematite, chlorite, glauconite, titanite, apatite, rutile, cassiterite?, and siderite.

Light Minerals.—Some of the characteristics of the "light" minerals of these rocks will be discussed briefly here.

(1) Quartz occurs generally as colorless glassy grains, although many of the grains are stained or flecked with limonite, hematite, magnetite or organic material. Many of the grains are very slightly etched on the surface. Many inclusions of tiny apatite and zircon and rarely titanite crystals occur in many of the quartz grains but no liquid or gaseous inclusions were noted. These mineral inclusions

show that probably most of the quartz in the Oakville was originally present in igneous rocks and did not come from quartz veins. Occasionally beautifully formed, tiny, short bipyramidal, hexagonal, glassy quartz crystals are noted. Usually these crystals have short prism faces but some have only the pyramid faces developed. These crystals are often sharp and glassy and must have grown in situ or have been transported only a very short distance after formation. No single ended prismatic quartz crystals were noted.

(2) Clay is the term used here because this fine grained material is composed of a mixture of minerals in such minute grains that they can be identified only with great difficulty. Kaolinite is probably the commonest mineral in this clay, but chlorite, limonite, sericite, calcite and other minerals in almost colloidal grains are present while somewhat larger (silt) grains of quartz, felspar, micas, etc., are also common and generally float off with the clay when the sample is being washed. Practically all the material that is so fine grained as to remain suspended in water for several seconds is classed as clay in this report. The exception to this is the calcite grains occurring in the sandstone cement and in some of the clays where the lime percentage has been determined.

(3) Calcite occurs in three forms: (1) in transparent, generally irregular, crystalline masses in the cement of the sandstone and sands; (2) as fairly hard, finely granular, generally round to botryoidal concretions or nodules, which usually include in them more or less clay and sand; (3) as minute almost colloidal grains intimately intermixed with clay particles. The calcareous concretions vary in size from one-fourth millimeter to ten centimeters in diameter but generally average between one and two millimeters.

(4) Chert is an unusually common mineral in the Oakville sands. It occurs in yellowish, black, gray, whitish, pink and pale green grains which show low birefringence and a fine aggregatal polarization under crossed nicols with the petrographic microscope. Some of the pale green grains are probably altered and more or less silicified volcanic rock fragments.

(5) Felspar also makes up a fair percentage of the Oakville sandstones and sands. All three of the common varieties of felspar, namely orthoclase, microcline and plagioclase are present. Microcline is often almost as abundant as orthoclase, which is an unusually high percentage for common sedimentary rocks. The orthoclase and part of the microcline and plagioclase are often more or less altered, in some cases becoming opaque. Many of the microcline and orthoclase grains are pale pink to flesh colored and have a pearly luster. The plagioclase is generally rather fresh and glassy and is white to colorless. Most of the plagioclase is albite and oligoclase but a few grains of andesine were noted. Many, but not all, of the plagioclase grains show albite twinning, often in fine parallel laminæ.

(6) Leverrierite, the principal mineral of bentonite and the mineral which absorbs water so readily as to induce the swelling and rapid slaking of bentonite or bentonitic clays makes up a great part of sample To 1 No. 2. Under the petrographic microscope this mineral appears as an almost colloidal substance composed of minute plates which usually appear pale brownish when massed together. The plates tend to cling together in small flattened aggregates. The index of refraction is below 1.52 and after leaving in 1.54 oil for three weeks a considerable part of this mineral showed an index of refraction above 1.54. The raising of the index of refraction of leverrierite if the mineral is immersed in oil for some time is apparently considered characteristic by Larsen.[1]

(7) Quartzite grains of a pink or pale gray color and having a fine texture are present rather commonly in some Oakville samples.

(8) Chalcedony is frequent in pale yellow, transparent, polished grains that show a wavy extinction and finely fibrous structure. Some bluish gray waxy grains are also occasionally found.

(9) Gypsum occurs in small, oblong, angular, transpar-

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[1]Larsen, E. S., The Microscopic Determination of the Nonopaque Minerals, U. S. G. S. Bull. 679, pp. 174, 193, 196, 245, 247, 251 and 254.

ent, platy grains that are generally bounded by cleavage planes.

(10) Dark gray or black platy grains usually above one-half millimeter in diameter are frequently noted. These have a non-crystalline to incipiently crystalline structure and are probably shale and slate grains.

(11) A few sharply angular generally elongated grains of an isotropic substance showing an index of refraction of about 1,.51 were noted in the bentonitic clay of the Oakville and are considered to be volcanic glass fragments. These grains generally give a banded appearance due to alteration and devitrification in certain of the cloudy bands. Some of the bands show uneven, very low interference colors, probably due to partial crystallization of the glass. These might be expected to be associated with so much bentonite.

(12) A small amount of whitish to transparent granular dolomite occurs in some of the Oakville sandstone cement.

Heavy Minerals.—The heavy minerals were separated from the light by means of bromoform. Magnetite in shiny, metallic black octahedrons or rounded grains and zircon in beautifully perfect crystals and partly eroded crystals or fragments of crystals are the two commonest heavy minerals. Most of the zircon is colorless but some crystals are pale yellow or pink. It is difficult to calculate the amount of limonite present because it occurs mainly as a stain on grains of other minerals and in powdery particles, or rusty scales. It is almost universal in Oakville rocks as staining material. Biotite and muscovite in shiny, pale brown to black or pale yellow to colorless flakes are often fairly common in the clays and finer sandstones and sands but are rare or absent in most of the typical Oakville sandstone samples. Ilmenite occurs in platy, often hexagonal, black metallic grains which are non-magnetic or only slightly magnetic. Barite in colorless crystalline masses showing its perfect cleavage is frequent in the sandstone cement. Red, pale brown, pink and yellowish rounded grains or dodecahedrons of garnet are frequently noted. Epidote occurs occasionally in rounded, pale yellow-green, translucent grains. Tourmaline showing a pale yellow or reddish-brown to green or black pleochroism is frequent in the heavy liquid separate in short to long almost flat ended prisms or eroded grains. Pyrite cubes are occasionally noted. Hematite occurs as stain in grains of other minerals generally. Chlorite occurs in minute flakes, disseminated through chert or altered volcanic rock fragments or in larger flakes due to the alteration of biotite. Glauconite is occasionally noted in well rounded or rarely botryoidal bright green to dark green grains that show aggregatal polarization. Titanite is rarely noted in yellowish diamond shaped crystals having very high birefringence. Apatite is found in colorless slender prisms up to one millimeter in length. Rutile is doubtfully identified as a mineral having a shiny almost metallic luster, and occurring in short tetragonal prisms. A similar mineral but having a brownish color and occurring in fairly slender prisms was possibly cassiterite. A very few pale creamy-brown rhombs of siderite were noted in the heavy liquid separate from To 1 No. 1.

ORIGIN

The origin of the Oakville is apparently the same as that of the Lagarto and this will be discussed at the end of the Miocene-Pliocene sections.

LAGARTO FORMATION

After a careful study of the Lapara and Lagarto sandstones, clays, and sands in Colorado County and a short trip to their type localities in Live Oak County and after discussing them with Mr. Alexander Deussen, who has mapped the territory of their outcrop throughout most of the Gulf Coastal Plain, the writer has followed Deussen in the conclusion that there are not enough distinctions between the Lapara and Lagarto to warrant a separate formational name. However, there are some thick beds of variegated pale pink and green, hard, unstratified clays between the typical yellow and gray mottled clays of the Lagarto and sandstones, sands and greenish clays of the

Oakville that are rather characteristic in appearance and may be of use as a horizon marker in well drilling. This group of clays and the associated sands is thus given the rank of a member (the Lapara) in the Lagarto formation, and is placed near the base of this formation. These clays do not hold their somewhat distinctive character over a considerable part of the Gulf Coastal Plain for no clays of this type were seen between Weimar and Flatonia. However, this series is recognizable in the description of well samples from the Texas Company's Schaffner No. 1 well, near Cat Spring. An unconformity is reported to exist at the top of the Oakville, but this was outside of Colorado County and was not observed along any of the roads traversed in Fayette County, though a careful search might reveal it. A description of the bluff of the Colorado River where these are best exposed in Colorado County and the petrographic description of these clays will be given later. Beds of loose sands and sandstones occur below these clays.

The clays of this Lapara member are conformable with the overlying Lagarto sandstones, sands and clays in this county.

LAPARA MEMBER

Description and Distribution.—This member of the Lagarto formation in Colorado County is only exposed along the Colorado River, in some of the small tributary creeks, near their mouths, and along Cummins Creek for a few miles below the Fayette County line. The sections given below will serve for a description of the Lapara. In addition to the clays and sandstones described in these sections are thick beds of loose, cross-bedded, calcareous sands containing large lumps of green clay as much as six inches in diameter. No beds of this latter type were found in Colorado County but they were seen a few miles across the line in Fayette County. The best section of Lapara rocks seen is found on the west bank of the Colorado River, about one-half mile below the Fayette County line on land belonging to Lee Stewart.

SECTION ON WEST BANK OF COLORADO RIVER ONE-HALF MILE BELOW FAYETTE COUNTY LINE

Station Tlp. 3.

1.	Black sandy loam soil	0′ to 3′
2.	Finely laminated, yellowish-gray, fine grained to medium grained, hard, calcareous sandstone. Is rather even bedded and weathers to brownish buff sand	10′
3.	Green and magenta-red, slippery, unstratified joint clay without recognizable lime nodules on the outcrop. Is mostly green in upper part and red below though mottlings of these colors are characteristic	6′
4.	Yellow and pale greenish or bluish-gray mottled, jointed, massive clay full of calcareous nodules 2 inches or less in diameter. Contains thin lenticular beds of argillaceous yellow sandstone ¼-inch to 2 inches thick	15′ to 23′
5.	Dark gray to black, massive, soapy, joint clay	0′ to 2′
6.	Pale green, bluish and pink variegated, jointed and unstratified clay which is rather low in lime and no calcareous nodules show on the surface. (Where No. 6 is thick, No. 5 is thinner.)	4′ to 8′
7.	Thin-bedded, irregular-bedded and cross-bedded, grayish buff, medium grained, calcareous standstone	0′ to 15′

(This sandstone is exposed below No. 6 only at the northwest end of the cliff, due to lenticularity of beds mainly but partly to the southeast dip. Farther southeast No. 6 extends to the water's edge. Some of the beds in this rock dip as much as 20°.)

Total Section	60′

The general dip of the clays and sandstones in this section is about one degree southeast. It is possible that the upper sandstone should not be included in the Lapara member, but its finely laminated character is slightly unlike most of the typical Lagarto. However, the sandstones at the base, No. 7, cannot be distinguished from those of the Lagarto.

A section on Brushy Creek, near Ellinger, showing the contact of the Lapara with the Lagarto proper is described below. An illustration of this section may be seen in Plate II.

SECTION ON EAST BANK OF BRUSHY CREEK, FOUR MILES SOUTHEAST OF ELLINGER

Lagarto.

1. Interbedded sandstone and laminated sandy clay of a buff color	5′
(Sandstone beds average 8 inches in thickness and clay 2½ inches.)	
2. Jointed unstratified yellow and gray mottled clay, containing calcareous nodules	0′ 6″
(Grades downward into No. 3.)	
3. Fine bluish-gray to buff (in upper part) unconsolidated sand becoming clayey near the top	3′
4. Fine-grained, whitish-gray sandstone containing lenses of sand	1′ to 2′

Lapara Member.

5. Finely laminated, soft, argillaceous, pale bluish gray sandstone weathering buff or whitish and containing harder lenses at the base	2′
6. Brownish yellow, greenish gray, and pink mottled, massive joint clay (No lime nodules noted)	3′ to 5′
7. Bluish to greenish-gray very fine clayey sand (in places reddish buff)	2′ to 4′
8. Fine, pale grayish buff sandstone and sand, cross bedded and often laminated and containing an impression of a palmetto leaf in one place, to bottom of creek	3′
(No. 8 resembles very closely the sandstone in No. 1.)	

The dip of the rather irregular-bedded sandstone and clay in this section is apparently one-half degree to one degree east of southeast.

Other exposures of similar rocks are found on the bank of Cryer Creek about 500 yards below the G. H. & S. A. Ry. bridge, on the south bank of the Colorado River, just above the average water level, two miles southeast of Shaws Bend, and in Fayette County in a cut made by a large tributary of Cummins Creek, about one-fourth mile west of Hatter Station, on the M. K. & T. R.R. The Lapara is thus seen to be found outcropping in Colorado County only along streams where the overlying rocks of the Lagarto have been cut through by erosion. The lower part of this member was studied only in a cursory way.

The average dip of the Lapara which is the same as the overlying Lagarto must be somewhat lower than the dip noted in the above sections because of the very pronounced downstream extension of the outcrop, although it is probably impossible to obtain reliable dips from the outcrops. The dip is estimated as about one-half degree (or fifty feet to the mile), southeast. The average of the dips read is about one degree (or ninety-two feet to the mile), southeast. However, it is very difficult to obtain any reliable dips in this member and it should be stated that these are mere approximations.

Thickness.—The base of the Lapara member should occur in Fayette County but is seen nowhere in Colorado County. However, the base of this member, and thus of the whole Lagarto formation, was not located by the present writer so that no estimate of the thickness from width of outcrop was possible. However, this member is extremely irregular in occurrence and seems to be lacking as a distinctive phase of the Lagarto between Weimar and Flatonia, although a careful study of this area might reveal it.

It is impossible to recognize the Lapara from ordinary well logs not accompanied by a good description of samples so that the only well of any value for this purpose that has been drilled in the Colorado County region is the Texas Company's well near Cat Spring, Austin County. In this well the drill passed through 500 feet of mottled red and green calcareous clay (between 1065 feet and 1565 feet). This seems an excessive thickness for the Lapara and it is possible that the color distinctions present on the surface may not hold for the buried clays and that part of these clays belong in the Oakville. Color difference, where it is the only distinction, is rather a slender basis for separating formations.

Paleontology of the Lapara Member.—Numerous foraminifera, Chara stems, Inoceramus prisms and a few small, secondary pelecypod(?) shell fragments in some of the sandstones are the only fossils found in the Lapara in Colorado County. However, in Fayette County, about seven miles north of Weimar, in the loose sand beds of the Lapara a few poorly preserved, unrecognizable bones and eroded bone fragments were observed. Unio shells have been described from the Lapara but the only Unio shells found on the Lapara outcrop in this region could be traced to remnantal patches of high terrace deposits.

The microscopic fossils are the same as those found in the rest of the Lagarto and will be discussed more fully under "Paleontology of the Lagarto." The camera-lucida drawings of the Lagarto and Oakville microscopic fossils, with the exception of *Textularia sagittula,* and the spores found in the Oakville but not noted in any part of the Lagarto formation, will serve for the Lapara member also.

Petrography of the Lapara.—The mineral content of the Lapara member is practically the same as the rest of the Lagarto. A comparison between the two parts of the Lagarto can be seen by referring to Tables 1, 2, 3, and 4.

The principal differences in the petrography of the two parts of the Lagarto are the presence of more abundant calcareous concretions in the Upper Lagarto and fewer in the Lapara and the frequent occurrence of manganiferous concretions in the Lagarto and not in the Lapara. There is also less sand present in most of the Lapara clay studied than in most of the Upper Lagarto clay, but a few samples of Upper Lagarto clay contain no more sand than do those of Lapara clay. The composition of the sandstones is very nearly identical and both are quite similar to the Oakville.

LAGARTO (EXCLUDING LAPARA MEMBER)

General Description.—The Lagarto, above the Lapara member, consists primarily of pale gray and buff mottled, unstratified, marly clays containing abundant calcareous nodules interbedded with pale yellowish to grayish-buff calcareous sandstones and sands. On the whole the clays are thicker and more prominent than the sandstones and form a black clay soil which is rather characteristic of the Lagarto formation as a whole. The black color is usually retained even where sandstones are prominent and the soil is sandy. The Lagarto is overlain unconformably by the Lissie formation.

The Lagarto marly clays are generally of the color described above but pale even-gray clays, magenta clays, and gray clays with buff, yellow-brown, magenta-pink and greenish variegations and mottlings also occur. The magenta clays, wherever seen, have been located immediately underneath the Lissie formation and probably owe their color to the downward migration of iron oxide so prominent in the Lissie. In other places the uppermost clays of the Lagarto are pale gray with yellow and brown mottlings and contain small round concretions of limonite and psilomelane or mixtures of the two instead of the iron oxide being noted as a uniformly distributed pink stain. No limonite concretions were seen in the Lagarto except at the top of this formation. Calcareous nodules are apparently universal in the Lagarto clays although they are more abundant in some places than in others. These concretions vary from the size of a hen egg to that of a pin head. The largest of them are generally hollow in the center. Black manganese dendrites and splotches occur almost universally along the cracks and closely-spaced jointing planes in these clays although they are rare in some beds. These joints generally have conchoidal surfaces and are greatly slickensided. This clay on weathering breaks down into tiny angular bits. It has a soapy feel when damp. This clay is practically always massive and shows no semblance of lamination except in the thin sandy clay strata between sandstone beds. The clay beds are very rarely persistent but even thick beds are usually found to be rather markedly lenticular if they are exposed for any distance horizontally. Clay partings between layers of irregularly bedded sandstones often partake of the irregular dips of the sandstones, one stratum, four to eight inches thick, having been observed to change from a dip of 20 degrees southwest to horizontal within a distance of 100 feet. On account of the prevalence of irregular bedding and the lack of extended exposures it is practically impossible to get dips that may be relied upon in the Lagarto. A photograph of Lagarto clay outcrops is found in Plate III. Several beds of a bright yellow-buff marl with a peculiar concretionary structure were also seen, notably four miles north of Columbus.

The Lagarto sandstones vary in color from grayish-white to buff and even pale pinkish in color. In general they are rather poorly sorted and most of them are either fine-grained or medium-grained, although beds of conglomeratic sandstones and grits occur locally. A very prominent and persistent feature of the Lagarto sandstones, especially those of finer grain, is the presence of numerous buff rounded or elliptical clay lumps or clay pebbles scattered through the rock. These pebbles resemble weathered Lagarto clay specimens and probably indicate contemporaneous erosion and deposition of certain parts of these sediments. the grains especially in the medium-grained and conglomeratic varieties of sandstone have a subangular or grit-like appearance even to the naked eye. Many black grains of chert are usually present which gives a somewhat speckled appearance to the coarser sandstones especially where light colored. A characteristic of Lagarto sandstones, practically wherever they are seen, is their extremely irregular bedding although in some places fairly thick beds not exhibiting stratification occur. Thick beds of sandstone may pinch out and become replaced by clay within a few feet horizontally although the individual beds are generally attenuated lenses. Beds of this sandstone exhibit large ripple marks in a cut made by South Harvey Creek near Borden. Cross-bedding is also very prominent among these sandstones being especially noteworthy in the ripple-marked sandstone one-fourth mile west of Borden. Here practically every direction and amount of dip is seen within a few hundred yards along South Harvey Creek, while a very short distance up stream the thin-bedded sandstones and clays are very nearly flat and comparatively regular for two hundred yards or more. A photograph of the latter outcrop is shown in Plate I, figure 1.

Another characteristic of this sandstone, like that of the Oakville is its high lime content. No examples of sandstone cemented with any other mineral than calcite were found in the Lagarto. More or less worn shall fragments, mostly, if not entirely from the Cretaceous, are commonly seen in the Lagarto sandstone while in some beds, especially in the vicinity of Borden, shell fragments, mostly of various genera and species of oysters like those in the Oakville, constitute fully one-fifth of the rock. Bone fragments and some unworn bones and teeth of land vertebrates are also found in this sandstone together with a number of sandstone, clay, quartz and chert pebbles up to two inches in diameter. However, this rock varies from a conglomeratic sandstone to a true sandstone without any pebbles except clay lumps within a few hundred feet horizontally and a few inches vertically.

Interbedded with the sandstones in many places are beds of loose, yellowish sand. These sands are also calcareous and often contain large chalky calcareous concretions as well as large lumps of buff or gray clay. Parts of these sands are often lithified due to the concentration of calcareous cementing material. An illustration of cross-bedded Lagarto sandstones and sands is shown in Plate I, figure 2. A rapid alteration of loose sands with fairly hard sandstones is generally the rule and the sand layers are apt to be thinner than those of sandstone, while in many cases the sand layers are mere partings. These sands also often contain shell fragments. The lime was evidently deposited with the individual beds or very soon after the deposition of each bed, otherwise this rapid alternation of sandstones and loose sands could hardly occur for the shape and size of the sand grains is generally the same in each case.

True conglomerates occur only very locally in the Lagarto and are commonest near the top of this formation, being frequently associated with the caliche-like non-fossiliferous fine-textured limestones. The best examples of calcareous conglomerates were noted two and one-half miles north of Altair. Here they occur near the top of the bluffs of the Colorado River, on both sides of the river. In the conglomeratic beds on the eastern side soft limestone pebbles up to five inches in diameter are common in one stratum and immediately overlie a limestone which appears identical to the pebbles. Sandstones are more prominent than the conglomerates here. Clay lumps, or pebbles, and pebbles of pink, dark gray and whitish chert and vein quartz are also common in these beds and a few pebbles of pink microcline felspar and pegmatite were noted on the west side of the river. Usually no true conglomerates occur but the Lagarto sandstones in most localities frequently contain small chert and quartz pebbles, while clay pebbles are almost universal as noted previously. Lagarto conglomerates are probably most prominent on the west bank of the river at the Altair bridge.

It is possible that the thin limy conglomerates and limestones described above belong to the Reynosa in its typical phase although the high terrace deposits found farther to the northwest, which Deussen considers to be equivalent in age to the Reynosa are characterized by an almost complete absence of lime. For this and other reasons given later these limestones are included in the Lagarto. Limestones of pinkish to white color and containing numerous black seams of manganese oxide, as well as a considerable percentage of subangular coarse to fine sand grains and even a few small pebbles, are exposed in two other rather restricted outcrops. One of these is in a small gully-like ditch near the road, about one-quarter of a mile north of the point where the Rock Island road branches off the Columbus-Altair road. Deussen[1] mentioned a 40-foot cliff of limestone in the Colorado River bluff southeast of this small exposure but this rather inaccesible outcrop was not seen by the writer.

The other exposure is located along Sandies Creek about six miles south-southwest of Rock Island, far removed from any Lagarto or other lime-bearing rocks. It is similar to the limestone described above. Manganese-bearing, pale gray clays and whitish calcareous sandstones are associated with the limestone and there is every gradation from the pale pink, fine grained, porous limestone to a limy sandstone. A few limestone lenses associated with conglomeratic sandstones were also noted three miles south of Altair near the mouth of Skull Creek.

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[1]Deussen, Alexander, Geology of the Coastal Plain Region of Texas. U. S. G. S., Prof. Pap. 126 (still in press).

Thick beds of limestone are also reported from wells drilled for oil near Eagle Lake and Lissie. The top of this limestone was encountered at 62 feet in the former and 143 feet in the latter well. This limestone is shown in the well logs found on pages 153-154. A fine-grained, hard, pink, non-fossiliferous limestone was also encountered near 1700 feet in the Columbus-Bernardo well north of Ramsey and a sample of this limestone was seen, but the parties having this well drilled would not furnish the log. The limestone looked very much like that noted at the top of the Lagarto above, but can hardly be in that formation because it is too deep. It is probably in the Oakville but may be Upper Corrigan.

Sections.—Some of the best exposed sections of Lagarto in Colorado County are given below. It should be stated that very few really good sections of Lagarto are found in this county.

SECTION ON SOUTHWEST BLUFF OF COLORADO RIVER TWO MILES ABOVE MOUTH OF HARVEY CREEK

1.	Medium grained, rather irregularly bedded, soft buff sandstone	6′	
2.	Brownish yellow and bluish gray colored joint clay. (Contains numerous lime concretions)	10′	
3.	Thin-bedded, fine-grained buff sandstone	3′	6″
4.	Bluish gray and brownish yellow mottled, joint clay with lime nodules. (similar to No. 2.)	4′	6″
5.	Covered to water's edge	3′	6″

The bedding of the Lagarto in the above section is not quite so irregular as usual. The dip here appears to be about four degrees southeast.

SECTION ON WEST BANK OF CUMMINS CREEK, ONE-FOURTH MILE ABOVE BRIDGE, THREE MILES NORTH OF COLUMBUS

1.	Dark brown to black clayey bottom soil	0′ to 4′
2.	Pale to deep buff and gray, massive clay with streaks of lime nodules near top and containing two slightly lenticular fine buff sandstone laminae. (The clay weathers to a rather uniform buff color)	8′ to 12′
3.	Very fine grained, thin bedded, soft, argillaceous, buff sandstone with spots and streaks of a pale gray color and containing clay pebbles, to water's edge. (The basal sandstone forms a flat ledge extending back as	

much as 12 feet from the water's edge at medium stage.) ....3′

The dip is apparently southeast not over one-half degree, but this is uncertain due to numerous minor irregularities of the bedding planes. It is very nearly horizontal.

SECTION BELOW EAST BRIDGE AT COLUMBUS ON WEST BANK OF COLORADO RIVER

1. Second terrace (Beaumont) silty sands and gravels of a gray to reddish color and containing an abundance of Unio and land snail shells..12′

Unconformity

2. Pink and greenish gray mottled clay containing abundant calcareous concretions .... 0′ to 2′
3. Massive bedded, pale greenish-white, calcareous sand, consolidated in part.. 7′
4. Greenish and red brown, mottled clay with lime concretions .... 2′ 6″
5. Massive greenish-white, sand or soft sandstone to water's edge at low stage.. 6′ 6″

The lower beds of Lagarto are rather regular and are exposed continuously for about 600 feet so that the dip could be calculated. It was found to be two feet per mile northwest, being apparently a slight reversal of the normal.

SECTION ON WEST BLUFF OF COLORADO RIVER THREE MILES NORTH OF ALTAIR ON THE TAIT FARM

Lissie

1. Gravelly gray, yellow, and red mottled, sandy clay, containing numerous round limonite concretions about the size of large buck shot. (Most of pebbles are chert and quartz and average about one-fourth inch in diameter although some up to three inches occur. They vary from angular to well rounded with the average about sub-rounded)..............10′

Unconformity

Lagarto

2. Fairly hard whitish, lime-cemented conglomeratic sandstone grading laterally and vertically into calcareous conglomerate locally and showing very irregular stratification or no bedding at all ....20′
3. Magenta-red, plastic, massive clay containing more or less abundant white spots.. 3′
4. Massive bedded, more or less pebbly, pale pinkish, friable, calcareous sandstone separated here and there by thin beds

of magenta, yellowish or whitish massive to laminated clay which are 1 inch to 8 inches thick. The sandstone beds are 1 to 5 feet thick and contain many chocolate colored to buff clay pebbles and scattered chert and quartz pebbles of a small size in the upper part. The lower 10 feet contain no pebbles except those of clay and is full of finely comminuted shell fragraments. Thickness of No. 4 to water's edge........25′

The dip of the majority of the beds in this section is two and one-half degrees to five degrees southwest and the strike N 20 degrees W.

SECTION ON WEST BLUFF OF CUMMINS CREEK ONE MILE NORTHWEST OF THE MOUTH OF REDGATE CREEK (STATION TLG. 3)

Lower Lissie (Reynosa)

1. Coarse flint gravel of red color capping hills in places.... 0′ to 3′

Unconformity

Lagarto

2. Whitish gray and yellowish-white, greatly cross-bedded and irregularly-bedded, conglomeratic sandstone interbedded with strata of bright to dull yellow sands. Most of the sandstone, conglomerate and sand contains abundant pebbles of yellow clay. All these beds are strongly calcareous. The sands are thin in the upper part but near the base one bed locally reached a thickness of 5 feet. Thickness of No. 2........................10′ to 30′

3. Ocher-yellow, concretionary, laminated marl containing calcareous concretions .... 0′ to 5′

4. Massive buff to bright yellow, gray-splotched, joint clay containing calcareous concretions up to 3 inches in diameter. Exposed ....20′ to 40′

   (The upper surface of this clay is irregular and undulatory and sandstone lenses occur in the upper 5 feet. The great variation in thickness is due to the irregular bedding of these rocks.)

   Covered with later terrace gravel and fill from outer edge of Cummins Creek bottom to bank of creek....20′

5. Cross-bedded sandstone, similar to No. 2 to water's edge. (No. 5 is exposed in the vertical bank of Cummins Creek) ....10′ to 20′

The dip is very irregular here but the more evenly-bedded, thin-bedded sandstone dips from one to six degrees varying in direction from southeast to southwest.

The average dip is thought to be about two degrees southeast here but this is hardly more than a guess.

The section is not all well exposed in one place but an attempt was made to supplement the beds not exposed in one place with those exposed along the strike a short distance away. That is why there is so much variation in thickness in the beds. This section thus gives some idea of the great irregularity of the Lagarto rocks.

Lagarto in Wells.—The samples placed in the Lagarto by the writer from the Texas Company's Schaffner No. 1, near Cat Springs are described as yellow, gray and some red and blue calcareous clay, containing calcareous concretions and more or less subangular, generally fine, sand. The yellow and gray clay is apparently similar to that so common in Lagarto outcrops. Several beds of sand and gravel are also logged but no samples were described, probably on account of the sand being too loose to make cores, and being mixed with the clay in the cuttings. The sandstones of the Lagarto, like those of the Oakville and Corrigan, seem to be much less prominent at considerable depth than in the outcrops.

Distribution of the Lagarto.—An idea of the distribution of the Lagarto is best obtained by referring to the geologic map. In general it may be said to outcrop over most of the northwestern third of the county, but it is covered over in the vicinity of the Colorado River and Cummins Creek by later gravels.

There are, however, certain peculiarities in the Lagarto distribution south of Columbus. Although they are covered over by younger deposits, especially river terrace materials in most of the area south of Columbus, Lagarto rocks are nevertheless exposed at the surface in disconnected patches for a distance of 15 miles south of the main contact of the Lagarto with the overlying Lissie formation. With the exception of one small patch six miles south of Rock Island these disconnected outcrops of Lagarto are found in the immediate vicinity of the Colorado River. The largest of these outcrops is found east and north of Altair where it forms prominent bluffs in places. Although it is natural for the southeast dipping Lagarto to extend downstream it would hardly continue at the surface for as much as 15 miles under normal conditions.

Two methods of accounting for this peculiarity of outcrop are: (1) there was a gentle but extensive high area in the original erosion surface at the top of the Lagarto in this region; (2) a slight uplift of the strata has occurred. On account of the great irregularity of the Lagarto bedding planes it is impossible to say with assurance which of these is the true explanation. However, a rather careful measurement of the dip of Lagarto along a clay-sandstone contact exposed for a horizontal distance of 465 feet, one-fourth mile south of the Columbus east bridge, gave a northwest or north dip of two feet to the mile. The second hypothesis is therefore considered more likely.

It is very difficult to find a natural explanation for the small outcrop of Lagarto rocks south of Rock Island other than by the uplift theory for Lissie beds are exposed in the very bed of Sandies Creek for several miles both upstream and downstream from this outcrop. It is possible that this patch may be Reynosa of the normal type found from DeWitt County south, but an uplift would seem probable in this event also.

Dip and Thickness.—As stated previously the dips obtained from Lagarto outcrops are extremely variable and unsatisfactory in general due to its lenticular bedding and cross-bedding. Very little aid can be obtained in this connection by consulting the logs of the few "rotary" wells that have been drilled in this region, for attempts at correlation are attended by considerable uncertainty. What are considered the most reliable exposed dips in the Lagarto average about one degree southeast or ninety two feet to the mile. Possibly a better estimate of the dip can be obtained by measuring the distance at right angles to the strike from the top of the pink and green clays of the Lapara member where exposed at the surface near the Fayette County line to the Schaffner No. 1 well near Cat Spring and noting the actual difference in elevation between this surface outcrop and the top of the pink and green clays in the Schaffner well. This difference in elevation was found to be 1080 feet in 18 miles, which gives a dip of 60 feet to the mile. The width of outcrops compared with the thickness of the Lagarto as near as can be told from well logs gives a nearly similar result so the regional dip of the Lagarto is estimated at 50 to 60 feet to the mile, the direction of dip being southeast.

The only dip that is thought to be reliable that is completely reversed from the normal is the two feet to the mile northwest dip noted in the west bank of the Colorado River, one-fourth mile south of Columbus. This is so slight as to be doubtful but the peculiar distribution of Lagarto south of Columbus seems to support it. A number of south, east, and southwest dips were noted but it is doubtful if any of these can be relied upon. From the direction of contacts between formations seen on the geologic map it would appear that the Lagarto north of Columbus dips nearly east while in the western part of the county it dips south-southeast. This could not be confirmed by actual dip observations on account of their uncertainty.

The thickness of the Lagarto, excluding the Lapara member, as nearly as can be told from a well section, is 740 feet in the Schaffner well, where the Lapara is tentatively distinguished on the basis of descriptions of samples from this well. Where the log only is obtainable it is unprofitable to attempt to distinguish the Lapara. The total thickness of the Lagarto including the Lapara member is estimated by means of well sections at 1250 feet in the northeastern part of the county, 1184 feet near Eagle Lake, and 1270 feet in extreme western Colorado County.

Paleontology.—One molar and two front teeth of the Lower Pliocene-Upper Miocene three-toed horse, *Protohippus perditus*, and many bone fragments were discovered in the Lagarto sand and sandstone about one and one-half mile northeast of Borden, at a locality called Dripping Springs. These teeth were very well preserved and almost certainly belong in the Lagarto. Also several complete fossil horse bones, which could not be identified specifically were found in the cross-bedded Lagarto sandstone, one-fourth mile west of Borden. A camera-lucida drawing of the teeth is found in figure 6.

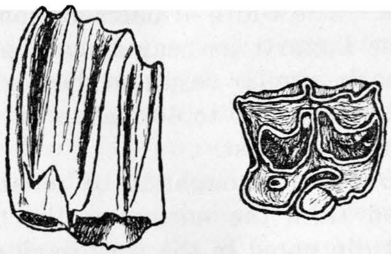

Fig. 6. Horse teeth from Lagarto, one and one-half miles north of Borden. Protohippus perditus Leidy. A. Side tooth; B. Right molar, M^3. 9/10 natural size.

Just as in the Oakville, more or less eroded secondary shells, probably mainly from the Cretaceous, are present in greater or less abundance in the Lagarto at many localities. In the neighborhood of Borden, along South Harvey Creek, these shell fragments are so abundant that the rock might be called a shell breccia. An *Exogyra arietina* and several small, thick shelled *Grypheas* prove that at least part of these shell fragments came from the Cretaceous and it is thus certain that at least part of the Cretaceous deposits of Texas were undergoing rapid erosion during Lagarto time. It is possible that part of the unrecognizable shell fragments came from the Lower Tertiary.

Small foraminifera of the same types as those in the Oakville are also quite frequent both in the Lagarto marly clays and in the sandstones at many localities. Most of these forms are below one-fourth millimeter in diameter. Some of the foraminifera are beautifully preserved but others are apparently more or less eroded or fragmentary. Unfortunately almost all the foraminifera found are long lived, unornamented forms so that it is impossible to tell how many of them are derived from Cretaceous and Eocene formations and how many belong in the Lagarto. However, at least one specimen was found which probably lived in Lagarto time. This was a very slender *Textularia* over one millimeter long with very prominently carinated chambers. It resembled *T. vertebralis,* but was not that species. Practically all the larger foraminifera (between one-fourth and one millimeter) are *Globigerina* and some of them may have lived in the Lagarto time. It seems very likely, nevertheless, from their type of preservation and the fact that they are accompanied by so many eroded Cretaceous shell fragments that at least the great majority of these small fossils were derived from the Cretaceous. It is possible that some of these foraminifera were derived from the marine Eocene beds, but none of the characteristic Eocene forms were noted.

A number of slender, white prisms of aragonite or calcite are commonly noted in the Lagarto rocks. Sometimes these show a good hexagonal outline. They are thought to be prisms from Cretaceous Inoceramus shells.

Small longitudinally fluted, cylindrical, calcareous bodies are frequent in some of the Lagarto samples. These resemble the stems of the calcareous alga, Chara, and are taken to be such. It seems rather peculiar that no Chara fruit was noted in any of the samples but a careful search failed to reveal any. The microscopic fossils of the Lagarto are shown in figure 5. Numbers 1, 3, 6, 8, 9, 10, 11, 12, 13, and 14 in figure 5 are found in the Lagarto. Numbers 2 and 10 are identical, the former specimen having been found in the Oakville and the latter in the Lagarto. Numbers 5 and 9 are also apparently identical and Numbers 12 and 13 may be this same species but the apical angles of the two latter is different from Number 9 and from each other. Numbers 11 and 14 have only been seen in the Lagarto, but may also occur in the Oakville.

Petrography of the Lagarto.—Although there is considerable variation in the lithology of the Lagarto the mineral content and to a lesser degree the organic content of the sand in the Lagarto is fairly definite in the majority of samples. Of course a large number of calcareous and manganiferous concretions are present in the sandy material washed from the clays and are absent in the sandstone, conglomerate and limestone.

TABLE 1

TABLE OF LOCALITIES AND MEGASCOPIC DESCRIPTIONS OF ROCK SAMPLES STUDIED PETROGRAPHICALLY

Station and Formation	Location of Station	Megascopic Description of Sample
Oakville To. 1	Near middle of La Grange Bluff, ½ mile south of La Grange, Fayette County.	No. 1. Medium to coarse-grained, yellowish gray, calcareous sandstone, containing many shell fragments. No. 2. Powdery, white, calcareous, arenaceous bentonite or tuff.
Lapara Member of Lagarto Tlp. 1	East bank of Cummins Creek, about Fayette County line, at ford below M. K. & T. bridge over Cummins Creek.	Rather coarse-grained, white, strongly calcareous unlaminated sandstone.
Tlp. 2	2½ miles north of Weimar on branch of Clear Creek.	Very fine-grained buff, calcareous, silty and argillaceous sandstone. (Rogers Polishing Earth.)
Tlp. 3	On south bank of Colorado River, ½ mile east of the Fayette County line.	No. 2. Fine grained, buff, laminated, calcareous sandstone. No. 3. Mottled magenta-red and grayish green, slightly calcareous, massive, joint clay. No. 4. Yellow and gray mottled, calcareous joint clay with abundant calcareous concretions. No. 5. Dark grayish-black, carbonaceous, slightly calcareous, massive clay. No. 6. Greenish and pale pinkish mottled, slightly calcareous, joint clay.
Lagarto Tlg. 1	3 miles west-southwest of New Ulm, 200 yards south of New Ulm-Frelsburg road.	Medium-gray, sandy, marly clay, containing abundant ferruginous, calcareous and manganiferous concretions.

Station and Formation	Location of Station	Megascopic Description of Sample
Tlg. 2	100 yards southwest of Columbus-Frelsburg road bridge over Redgate Creek.	Medium-grained, deep buff, calcareous loose sand.
Tlg. 3	West bluff of Cummins Creek, ½ mile above mouth of Redgate Creek.	No. 3. Buff, somewhat concretionary marl containing numerous fine to coarse sand grains.
Tlg. 4	3 miles northeast of Weimar, 200 yds. east of bridge over North Harvey Creek.	Buff and pale gray mottled, calcareous, joint clay containing few calcareous concretions.
Tlg. 5	Near top of south bluff of South Harvey Creek, 1½ miles N. E. of Borden (Protohippus perditus locality).	Medium to coarse-grained, conglomeratic, calcareous sandstone containing abundant shell and bone fragments and a few well preserved horse teeth.
Tlg. 6	On north bluff of So. Harvey Creek. 1 mile northeast of Borden.	Pyritiferous marly, medium gray clay.
Tlg. 7	Rocky banks of So. Harvey Creek, 1 mile northeast of Borden.	Soft, medium-grained, calcareous sandstone containing abundant shell fragments and a few clay lumps.
Tlg. 8	In cut on north side of Houston-San Antonio highway, ½ mile W. of Glidden.	Dirty, pinkish-buff, fine-grained, calcareous, hard sandstone containing many lumps of magenta to buff clay and showing manganese dendrites.
Tlg. 9	In cut on both sides of Houston-San Antonio highway, 2 miles south east of Alleyton.	No. 1. Medium-grained, pale grayish to yellowish white, calcareous sandstone, containing buff clay lumps. No. 2. Grayish-white, slickensided, jointed marl containing numerous calcareous concretions.

Station and Formation	Location of Station	Megascopic Description of Sample
Tlg. 10	Near base of high, rocky bluff of Colorado River, 2½ miles north of Altair.	Pale pink, medium-grained, calcareous sandstone containing numerous shell fragments.
Tlg. 11	¼ mile northwest of Tlg. 10, near top of rocky bluff.	White, strongly calcareous, conglomeratic sandstone.
Tlg. 12	East bank of Sandies Creek, 4 miles south-southwest of Rock Island.	No. 1. Soft, pink to white, sandy limestone containing numerous streaks of psilomelane. No. 2. Friable, whitish, strongly calcareous, medium-grained sandstone. (Grades into No. 1.)
Tlg. A	Type locality, ¼ mi. west of Lagarto, Live Oak County.	No. 1. Pale grayish buff, calcareous sandstone containing numerous buff clay lumps. No. 2. Pink, buff and gray mottled, jointed marl containing numerous calcareous concretions.
Lissie		
Ql. 1	West bank of San Bernard River at Bernard-Cat Spring road bridge.	Red, orange, and gray mottled, non-calcareous, very argillaceous sand.
Ql. 2	Railroad cut ¼ mile south of Knarf.	Whitish and reddish mottled, argillaceous, quartz-felspar conglomerate.
Ql. 3	1½ miles northwest of Ramsey where small creek crosses San Antonio-Houston highway.	Orange-red, sandy and clayey, non-calcareous gravel containing abundant limonite concretions.
Ql. 4	2 miles southeast of Oak Grove near North Fork of Miller Creek.	Dirty, buff, loose, surface sand. (Weathered Lissie.)

Station and Formation	Location of Station	Megascopic Description of Sample	
Ql. 5	Banks of East Sandies Creek, 3 miles west of Rock Island.	No. 1.	Soft white, argillaceous, non-calcareous sandstone with red and yellow mottlings.
		No. 2.	Pale sulphur — yellow sandy clay.
		No. 3.	White and red mottled, non-calcareous, bentonitic clay.
Ql. 6	West bank of Colorado River, ¼ mi. north of Garwood.	No. 3.	Pinkish yellow, very slightly calcareous, loose sand.
		No. 5.	Brownish-orange, non-calcareous, gravelly sand.
Beaumont Qb. 1	Same location as Q1.6, overlying the Lissie sand.	Magenta-red calcareous clay containing calcareous concretions.	
Qb. 2	Johnson - Pryor Ranch, Wharton County, on west bank of Colorado River nine miles south-southeast of Garwood. (Elephas imperator locality.)	Magenta-red calcareous clay containing large lime concretions.	

TABLE 2
TABLE SHOWING SORTING OF COLORADO COUNTY SAMPLES

Station	32-16	16-8	8-4	4-2	2-1	1-½	½-¼	¼-⅛	⅛-1/16	Below
To. 1 No. 1	....	....	....	tr.	1	54	30	8	5	2
To. 1 No. 2	....	....	....	....	....	tr.	3	17	5	75
Tlp. 1	....	....	....	3	5	47	25	15	4	1
Tlp. 2	....	....	....	....	....	tr.	tr.	1	50	49 (half silt)
Tlp. 3 No. 2	....	....	....	....	1	tr.	5	70	20	4
Tlp. 3 No. 3	....	....	....	0.1*	0.2*	0.3	0.2	0.3	1.9	97
Tlp. 3 No. 5	....	....	....	....	tr.*	0.6	0.4	0.5	0.5	98
Tlp. 3 No. 6	....	....	....	tr.*	tr.*	0.15	0.25	0.2	1.2	98
Tlg. 1	....	....	3*	1*	1	3	4	5	1	82
Tlg. 2	....	....	5	3	2	13	29	38	15	5
Tlg. 3 No. 3	....	....	....	....	tr.	2	5	6	2	85
Tlg. 4	....	....	....	....	....	tr.	tr.	tr.	tr.	99 +
Tlg. 5	....	10 bone	2	2	3	35	21	15	2	10
Tlg. 6	....	....	....	....	....	tr.	0.15	0.35	1.45	98
Tlg. 7	....	....	5 clay	5	2	35	32	15	5	1
Tlg. 8	....	5 clay	3 clay	1 clay	1 clay	tr.	tr.	12	68	10
Tlg. 9 No. 1	....	....	....	tr.	8	35	31	15	12	1
Tlg. 9 No. 2	....	....	tr.*	tr.*	1	3	7	7	2	80
Tlg. 10	....	....	2 clay	1	1	20	33	33	8	2
Tlg. 11	tr.	tr.	2	8	10	12	25	2	1	tr. (clay pebbles not included)

Tlg. 12 No. 1	....	....	....	....	tr.	1	6	15	18	60
Tlg. 12 No. 2	....	....	....	....	tr.	12	15	39	27	7
Tlg. A No. 1	....	....	2 clay	3 clay	1	16	28	37	12	1
Tlg. A No. 2	....	....	....	tr.*	tr.*	tr.	1	3	1	95
Ql. 2	....	....	1	10	16	16	tr.	tr.	tr.	54
Ql. 3	3	2	23	15	12	15	15	14	1	7
Ql. 4	....	....	....	....	1	30	35	30	4	tr.
Ql. 5 No. 1	....	....	....	....	tr.	15	26	30	4	25
Ql. 5 No. 3	....	....	....	....	tr.	tr.	tr.	1	1	98
Ql. 1	....	....	....	tr.	1	17	15	11	6	50
Ql. 6 No. 3	....	....	....	1	2	27	41	18	4	7
Ql. 6 No. 5	4	1	3	5	8	51	9	5	2	12
Qb. 1	....	....	....	tr.*	tr.*	tr.	tr.	1	1	98
Qb. 2	....	1*	....	....	....	tr.	tr.	1	1	97
Average Lapara S. S.	....	....	....	1	2	15	10	29	25	18
Average Lapara Clay	....	....	....	tr.*	tr.*	0.35	0.3	0.3	1.3	97.5
Average Lagarto S. S.	tr clay	1 clay	2	3	3	24	24	23	16	4
Average Lagarto Clay	....	....	0.4*	0.1*	0.3*	1.3	3	5	4	86
Average Lissie Gravel	Above 16 mm. 12	2	8	11	10	26	7	5	1	18
Average Lissie Sand and Clay	....	....	....	tr.	1	18	23	18	4	36
Average Beau-mont Clay	....	1*	tr.*	1*	1*	tr.	tr.	1	1	95

*Calcareous Concretions only.

TABLE 3

TABLE OF LIME PERCENTAGES

Station and Formation	Percent	Station and Formation	Percent
Oakville		*Lissie*	
To 1 No. 1	40	Lower Lissie	
To 1 No. 2	35	Ql 2*	None
Lapara Member		Ql 3*	None
Tlp 1*	46.10	Ql 4	None
Tlp 2*	42.07	Ql 5 No. 1	None
Tlp 3 No. 2	35	Ql 5 No. 2	None
Tlp 3 No. 3*	14.57	Ql 5 No. 3*	0.65
Tlp 3 No. 5*	16.45	Upper Lissie	
Tlp 3 No. 6*	6.50	Ql 1*	1.14
Tlp 3 No. 4*	34.20	Ql 6 No. 3	5
Lagarto		Ql 6 No. 5	tr.
Tlg 1	20	*Beaumont*	
Tlg 2	15	Qb 1*	12.43
Tlg 3 No. 3*	35.00	Qb 2	17
Tlg 4*	18.25	Average Lapara Sandstone	41.05
Tlg 5	40		
Tlg 6	20	Average Lapara Clay	12.51
Tlg 7*	45.73	Average Lagarto Sandstone	38.45
Tlg 8*	45.45		
Tlg 9 No. 1*	40.00	Average Lagarto Clay (Marl)	26.38
Tlg 9 No. 2	30		
Tlg 10	30	Average Lissie Gravel	None
Tlg 11	45	Average Lissie Sand & Clay	tr.
Tlg 12 No. 1*	52.68		
Tlg 12 No. 2	40	Average Beaumont Clay	14.71
Tlg A No. 1	45		
Tlg A No. 2	35		

*Determined by chemical analysis.

TABLE 4

TABLE SHOWING COMPOSITION OF COLORADO COUNTY FORMATIONS

Locality and Stratum	Actinolite	Anatase?	Apatite	Barite	Biotite	Calcareous Nodules	Calcite	Cassiterite?	Chalcedony	Chert	Chlorite	Clay	Corundum?	Diopside	Dolomite	Epidote	Felspar	Fluorite	Garnet	Glauconite	Gypsum	Hematite	Hornblend	Ilmenite	Kyanite	Leverrierite	Limonite	Limonite Nodules	Magnetite	Monazite	Muscovite	Opal	Pegmatite	Psilomelane Nodules	Pyrite	Quartz	Quartzite	Rutile	Siderite	Slate and Shale	Sphalerite	Staurolite	Strontianite	Titanite	Tourmaline	Tremolite	Zircon	Zoisite	Forams	Inoceramus Prisms	Shell Fragments	Carbonaceous Matter	Chara Stems
To 1 No. 1 (s. s.)	....	....	....	c	f	....	24	r	a	16	r	2	....	....	f	f	10	....	f	r	....	f	....	c	....	....	a	....	a	....	....	....	....	....	r	31	1	f	r	....	....	r	....	f	f	....	c	....	....	f	15	....	f
To 1 No. 2 (tuff)	....	....	x	....	x	....	32	....	....	3	x	....	....	....	....	x	4	....	....	....	c	....	....	x	....	53	....	....	x	....	a	....	....	....	....	5	....	....	....	....	....	....	....	....	....	....	x	....	3	a	....	....	f
Tlp 1 (s. s.)	....	....	....	1	....	....	40	....	3	17	....	x	....	....	....	x	7	....	x	....	....	....	....	x	....	....	....	....	x	....	x	....	....	....	x	32	....	x	....	....	....	....	....	x	x	....	x	....	....	....	....	....	....
Tlp 2 (fine s. s.)	....	....	x	....	2	....	20	....	....	3	x	25	....	....	....	x	10	....	x	....	....	....	....	x	....	....	x	....	x	....	5	....	....	....	....	31	....	....	....	....	....	....	....	....	....	....	x	....	4	....	x	....	....
Tlp 3 No. 2 (s. s.)	....	r	r	f	c	....	26	r	1	8	....	4	r	....	c	f	5	....	r	f	r	c	r	f	....	....	a	....	a	....	c	....	....	....	f	47	f	f	....	1	....	r	....	....	f	....	a	....	8	....	....	....	f
Tlp 3 No. 3 (clay)	....	....	r	....	f	1	16	....	....	a	r	80	r	....	....	....	a	....	r	f	f	1	....	f	....	....	....	....	c	....	....	....	....	....	c	1	....	....	....	....	....	r	....	....	r	....	f	....	a	....	....	....	....
Tlp 3 No. 5 (clay)	....	....	r	....	....	a	15	....	c	a	....	91	....	....	....	....	a	....	....	....	....	....	....	f	....	....	....	....	c	....	....	....	....	....	1	1	f	f	....	....	....	r	....	r	r	....	c	....	a	....	....	2	....
Tlp 3 No. 6 (clay)	....	r	r	r	....	1	4	....	r	a	r	91	f	....	....	....	a	....	c	....	f	1	....	f	....	....	....	....	c	....	r	....	....	....	r	2	c	r	....	....	....	....	....	r	r	....	f	....	f	....	....	....	....
Tlg 1 (clay)	....	....	....	....	....	8	7	....	....	2	....	70	....	....	....	....	1	....	....	....	f	....	f	f	....	....	a	c	a	....	....	....	....	4	f	8	....	r	....	....	....	....	....	....	f	....	a	....	c	....	....	....	....
Tlg 2 (sand)	....	....	....	f	f	....	5	....	f	13	r	10	....	....	....	r	10	....	f	r	....	c	....	f	....	....	a	c	c	r	f	....	....	....	r	55	....	r	....	....	....	....	....	....	f	....	f	....	2	c	5	....	f
Tlg 3 No. 3 (marl)	....	....	....	....	2	a	25	....	a	2	....	52	....	....	....	....	1	....	....	....	c	f	....	a	....	....	1	....	c	....	1	....	....	....	....	12	....	f	....	....	....	....	....	....	....	....	f	....	4	....	....	....	....
Tlg 4 (clay)	....	....	....	....	....	5	12	....	....	a	x	80	x	....	....	x	c	....	x	....	f	x	x	f	....	....	1	....	f	....	....	....	....	c	....	2	....	x	....	....	....	....	....	....	x	....	x	....	c	....	....	....	....
Tlg 5 (cong. s. s.)	....	....	....	....	c	....	25	....	a	15	....	5	....	....	....	f	10	....	....	....	....	c	....	a	....	....	a	....	1	....	f	....	....	....	....	25	....	r	....	....	....	....	2	r	....	....	c	....	1	x	15	c	r
Tlg 6 (clay)	....	....	....	....	c	f	10	....	....	a	r	85	....	....	c	r	a	....	r	....	....	....	....	f	....	....	....	....	f	....	f	....	....	....	1	2	....	....	....	....	....	....	....	r	r	....	r	....	1	c	....	....	f
Tlg 7 (s. s.)	....	....	....	c	....	....	30	....	c	13	....	9	r	....	....	r	8	f	....	....	....	a	....	f	....	....	1	....	c	....	c	f	....	....	c	24	....	....	....	....	....	....	1	....	....	....	r	r	f	....	12	....	r
Tlg 8 (s. s.)	....	....	....	....	1	....	25	....	a	13	c	8	....	....	1	r	13	....	r	r	....	a	r	f	....	....	2	....	a	....	2	....	....	a*	....	35	....	....	....	....	....	....	....	r	....	....	a	....	....	....	....	....	....
Tlg 9 No. 1 (s. s.)	....	r	....	....	f	....	18	....	....	12	....	a	....	r	1	c	14	....	f	....	....	a	....	a	....	....	a	....	1	r	r	....	....	....	....	52	....	f	....	....	....	r	....	f	f	....	c	....	....	....	1	....	f
Tlg 9 No. 2 (marl)	....	....	x	....	x	9	15	....	....	2	....	63	....	....	....	x	1	....	....	....	....	....	x	x	....	....	....	....	x	....	....	....	....	1	....	8	....	x	....	x	....	....	....	x	x	....	x	....	1	x	....	....	....
Tlg 10 (s. s.)	....	....	x	....	....	....	13	....	c	9	....	4	....	....	....	....	15	....	x	....	x	1	....	x	....	....	x	....	x	....	....	....	....	....	....	51	....	....	....	....	....	....	....	x	x	....	x	....	r	r	6	....	....
Tlg 11 (cong. s. s.)	....	....	....	....	....	....	45	....	....	10	....	x	....	....	....	x	10	....	....	....	....	x	....	x	....	....	x	....	x	....	....	....	....	....	....	35	....	....	....	....	....	....	....	....	x	....	x	....	....	....	....	....	....
Tlg 12 No. 1 (ls.)	....	....	....	....	1	....	50	....	....	4	....	25	....	....	....	....	4	....	....	....	....	f	....	f	....	....	....	....	x	....	x	....	....	2*	....	14	....	....	....	....	....	....	....	....	....	....	x	....	....	....	....	....	....
Tlg 12 No. 2 (s. s.)	....	r	....	c	a	....	35	....	f	10	....	5	r	....	....	c	7	....	f	....	r	....	....	f	....	....	....	....	c	....	a	f	....	a*	r	42	....	r	....	....	....	....	....	....	f	....	a	....	....	....	....	....	....
Tlg A No. 1 (s. s.)	....	....	r	f	c	....	41	....	....	10	....	6	r	....	....	....	2	....	r	....	....	c	r	c	....	....	c	....	a	....	....	....	....	....	....	40	....	r	....	....	....	....	r	f	f	....	a	....	....	....	....	....	....
Tlg A No. 2 (marl)	....	....	....	f	....	3	27	....	....	1	r	65	r	....	....	....	a	....	r	....	....	c	r	f	r	....	a	....	c	....	....	r	....	c	....	3	....	r	....	....	....	....	....	r	r	....	c	....	....	....	....	....	f
Ql 2 (cong. clay)	....	....	....	....	c	....	....	r	....	5	....	50	....	....	....	r	14	....	....	....	....	a	c	f	....	....	1	....	c	....	r	....	5	....	....	25	....	....	....	....	....	....	....	f	r	....	c	....	....	....	....	....	....
Ql 3 (grav.)	....	....	r	....	....	....	....	r	f	20	....	3	....	....	....	....	a	....	f	....	....	1	....	c	r	....	3	32	a	....	f	....	....	c	r	40	c	r	....	c	....	....	....	....	c	....	a	....	....	....	1	....	....
Ql 4 (sand)	....	....	....	....	....	....	....	....	....	21	....	c	....	....	....	....	f	....	....	....	....	....	....	f	....	....	1	....	a	....	....	....	....	....	....	78	....	....	....	....	....	....	....	....	....	....	c	....	....	....	....	....	....
Ql 5 No. 1 (s. s.)	....	....	....	....	....	....	....	....	3	10	....	22	....	....	....	f	1	....	....	....	....	c	....	f	....	....	1	....	a	....	....	....	....	....	....	63	a	....	....	....	....	....	....	....	f	....	a	....	....	....	....	....	....
Ql 5 No. 3 (bentonite)	....	....	....	....	....	....	....	....	c	a	....	25	....	....	....	....	a	....	....	....	....	a	....	f	....	70	1	....	c	....	a	....	....	....	....	3	f	r	....	....	....	....	....	r	f	....	c	....	....	....	....	....	....
Ql 1 (sdy. clay)	....	....	....	f	....	....	....	f	c	4	....	40	....	....	....	r	a	....	f	....	....	4	....	c	....	....	5	2	a	r	f	f	....	....	....	45	a	f	....	c	....	....	....	....	f	....	a	....	....	....	....	....	....
Ql 6 No. 3 (sand)	....	....	....	....	1	....	3	....	....	5	f	1	....	....	....	....	20	....	f	....	....	a	a	f	....	....	2	....	c	....	a	....	....	....	....	67	....	....	....	....	....	....	....	....	....	....	f	....	....	....	1	....	f
Ql 6 No. 5 (grav.)	r	....	f	....	....	....	....	r	f	5	r	7	....	....	....	f	10	....	f	....	....	3	f	f	....	....	4	....	a	....	c	....	3	....	....	67	a	....	....	....	r	....	....	f	f	r	c	....	....	....	....	....	....
Qb 1 (clay)	....	....	....	....	f	5	7	r	....	a	....	85	....	....	....	....	a	....	....	....	....	1	f	....	....	....	f	....	f	....	r	....	....	....	....	2	....	....	....	....	....	....	....	....	....	....	r	....	....	....	....	a	r
Qb 2 (clay)	....	....	r	r	f	7	10	....	....	a	....	79	....	....	....	r	1-	....	....	....	....	1	c	....	....	....	f	....	r	....	f	....	....	....	....	2	....	....	....	....	....	....	....	r	r	....	r	....	f	....	a	a	....
Average Lapara Sandstone	....	r	r	c	a	....	30	r	1	9	r	10	r	....	r	f	7	....	r	r	r	r	r	f	....	....	c	....	a	....	1	....	—	....	f	37	r	r	....	c	....	r	—	r	f	....	c	....	4	....	r	....	r
Average Lapara Clay	....	r	r	r	r	1	10	....	r	a	r	86	r	....	....	....	a	....	f	r	f	1	....	f	....	—	....	—	c	....	r	....	—	—	c	1	f	r	....	....	....	r	....	r	r	....	f	....	a	....	....	c	....
Average Lagarto Sandstone	....	r	r	f	c	....	27	....	c	12	r	5	r	r	a	f	12	r	r	r	r	c	r	c	....	....	a	....	a	r	c	r	—	c*	r	37	....	r	....	....	....	r	a	r	f	....	a	r	a	r	5	....	f
Average Lagarto Clay	....	....	r	....	a	8	13	....	f	1	r	68	r	....	r	r	1	....	r	....	f	f	r	f	r	—	1	*r*	c	....	r	....	—	1	c	6	....	r	....	r	....	....	....	r	r	....	f	....	1	f	....	....	f
Average Lissie Gravel	r	....	r	....	f	....	—	r	f	28	r	20	—	....	—	r	7-	....	f	—	—	1	f	f	r	....	2	10	a	....	f	....	2	*f*	—	30	c	....	....	f	r	....	—	r	f	r	c	....	—	....	*f*†	....	....
Average Lissie Sand and Clay	....	....	....	r	a	—	*f*	r	1	10	r	28	—	....	—	r	5	....	f	—	—	1	f	f	....	2	2	1	a	r	c	f	....	—	—	51	c	r	....	f	....	....	—	r	f	....	a	....	—	....	*r*	....	r
Average Beaumont Clay	....	....	r	r	f	6	8	r	....	a	....	83	—	....	—	r	a	....	....	—	—	1	c	—	....	—	f	—	f	....	f	....	—	—	—	2	....	....	....	....	....	....	....	r	r	....	r	....	f	....	a	a	r

Note: Figures indicate percentages.
Letters indicate relative abundance of minerals occurring in traces only; i. e., a: abundant, c: common, f: frequent, r: rare, x: present in traces. —: noteworthy absence or scarcity of mineral, indicating difference in formation.

*Psilomelane streaks, not nodules.

†Silicified.

The approximate composition and characteristics of the sixteen samples of Lagarto which were studied in detail are tabulated in tables 1, 2, 3, and 4, pages 84-90, and by a study of these tables a fairly definite idea of the formation can be obtained. It should be noted here that the samples studied were selected so that practically all the variations in lithology of the formations represented in the tables will be brought out. Some of these samples are much more widespread in occurrence than others. Tlg 8, Tlg 6, Nos. 1 and 2, and Tlg 4 are some of the more typical samples. The data obtained on the Lagarto formation are probably more nearly accurate than those for the other formations because a greater number of samples were studied.

A few Lagarto samples were collected from the type locality of this formation in Live Oak County and two of these are included in the table for the sake of comparison.

Minerals of the Lagarto.—The minerals noted in the Lagarto are similar in appearance and in the percentages present, with a few exceptions, to those of the Oakville. One of these exceptions is the lack of leverrierite in any of the Lagarto clays seen and also the absence of any volcanic glass grains. A deep greenish-blue mineral occurring in rounded or hexagonal plates which agrees rather closely with corundum but which may be a blue uniaxial chlorite is also found rarely in Lagarto rocks. This mineral appears isotropic but gives a centered uniaxial cross in convergent light. Strongly pleochroic red-brown, prismatic crystals thought to be staurolite are also noted in the Lagarto rarely. Other rare minerals noted in the Lagarto and not in the Oakville include anatase, diopside, fluorite, hornblend, kyanite, monazite ?, opal, and zoisite. These are so rare that they may have been present in the Oakville but were overlooked. Siderite was noted as rare in the Oakville but not at all in the Lagarto.

A few more common and possibly characteristic minerals found in the Lagarto and not in the Oakville are psilomelane concretions and dendrites and strontianite. These are described on the following page where the two formations are compared. The Lagarto above the Lapara member is very similar in composition to the Lapara member in mineral composition. Their slight differences have already been noted and shown in Table 4.

An analysis was made of a typical sample of Lagarto sandstone from Station Tlg 9 for the purpose of checking the felspar percentage and the relative abundance of potash and soda-lime felspars. This analysis was made by Mr. J. E. Stullken of the Division of Industrial Chemistry, Bureau of Economic Geology and Technology. It is as follows:

Analysis of Lagarto Sandstone from Station Tlg 9

Silica	51.40
Alumina	5.18
Ferric Oxide	0.77
Lime	24.57
Magnesia	none
Sodium Oxide	1.29
Potassium Oxide	0.92
Loss on Ignition	15.43
Total	99.56

It is nearly certain that all the soda and potash in this analysis comes from the felspar. If an average between orthoclase and albite-oligoclase is taken for the total felspar in this sample and all the soda and potash are considered to come from felspar then 3.05 per cent of the alumina and 10.47 per cent of the silica in the analysis will go to the felspar. These substances on being added give 15.73 per cent as the total felspar in the sample. Of the total felspar 6.45 per cent would be orthoclase and potash-microcline and 9.28 per cent plagioclase and soda-microcline. It seems likely that part of the microcline belongs to the soda-microcline variety from the apparent relative abundance of the three varieties of felspar found in petrographic analyses.

Comparison of the Oakville and Lagarto.—After the microscopic study of the Oakville and Lagarto was completed the writer was inclined to lump the Oakville and Lagarto into one formation, so great was their similarity and he is still doubtful whether they are both of formational rank. The reasons for separating them have already been given but it is often very uncertain where to draw the contact line. The same general physical conditions very probably existed throughout Oakville-Lagarto time and it appears that at least some of their vertebrate fossils are practically identical.

Mineral Composition.—One of the more striking facts brought out by this petrographic study is the abundance of flesh-pink, translucent grains. These are mostly microcline and orthoclase felspar but pink chert is also abundant. Not as many of these pink grains were seen in the few samples of Oakville studied as in the Lagarto but more Oakville samples should be studied before saying that this is a difference. Much of this felspar is microcline. The plagioclase grains are mainly colorless. Beautiful transparent, polished, honey-yellow grains that resemble amber under the binocular microscope, have a finely fibrous structure and are thought to be chalcedony, are present in many Oakville and Lagarto samples. Much of the chalcedony noted in these formations in Table 4 was of this type. Yellowish-white strontianite veins and prismatic fragments were found in a few Lagarto samples but no strontianite was observed in the Oakville. Shiny black botryoidal concretions of psilomelane, possibly mixed with pyrolusite occur in several samples of Lagarto clay and have not been noted in the Oakville; also the finer sandstone and the limestone of the Lagarto often shows manganiferous dendrites. Manganese concretions and stains have not been identified in the Oakville. Also the rounded buff to pinkish clay lumps or clay pebbles so characteristic of the Lagarto sandstone seem to be less abundant and of a larger size in the Oakville sandstone. Small crystals of zircon and magnetite are common in small amounts in both formations. These are much commoner in general than the other heavy minerals. Gray, black, whitish and yellow chert grains together with the pink chert already mentioned make up about 15 per cent of the sand grains in both formations. This is very different from the Catahoula sandstone described by Goldman. Tuffaceous beds were noted in the basal Oakville but are not present in the Lagarto.

The cement in the sandstones of both formations seems to be almost entirely calcite although very small amounts of barite and dolomite are often present.

Fossils.—The fossils, including foraminifera, Chara stems, shell fragments, and Inoceramus prisms, are about the same in both formations. All the foraminifera seen in the Oakville except *Textularia sagittula?* (figure 5, No. 4) are also found in the Lagarto, while *Textularia* cf. *vertebralis, Pulvinulina* ? sp. (figure 5, No. 11) and *Globigerina* sp. (figure 5, No. 14) were noted in the Lagarto, but not in the Oakville. A fragmentary diatom and a number of tiny spore-like bodies were also noted in the Oakville but not in the Lagarto. The uppermost Lagarto beds seem to be much less fossiliferous than do the lower.

Rounding of Grains.—The rounding of the grains is also similar in the Oakville and Lagarto. About two per cent of the grains (mostly quartz) in the average Oakville-Lagarto sandstone are beautifully rounded and polished. Also about 20 per cent of the grains are subrounded. The greater portion of the grains are subangular, comparatively few grains occurring which are not somewhat worn on the edges.

Lime Content.—The lime content of the two formations is also approximately the same.

Sorting.—The sandstones of the Oakville and Lagarto formations are quite similar in the sorting or sizing of their grains except that the maximum separate is probably coarser on the average in the Oakville than in the Lagarto. In all the sandstone samples of these two formations studied, the next most abundant separate to the maximum is the next finer. The sorting is rather poor in the majority of cases, that is, the maximum is not very pronounced. This sorting resembles fairly closely the diagrams Goldman[1]

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[1]*Op. cit.*, pp. 169-170.

gives for stream and delta deposits, especially the former.

Five of the Lagarto sandstone samples show a (1/4-1/8 mm.) maximum, four a (1-1/2 mm.), two (1/2-1/4 mm.), and two (1/8-1/16 mm.). A small second maximum is present only in the samples having many clay lumps or other pebbles present. Samples Tlg 2 and Tlg 11 show the next coarsest separates to be the next to the largest.

The sand in the Lagarto clays is mostly between one-fourth and one-sixteenth millimeters in diameter. In some samples lime concretions from one to ten millimeters in diameter make up the greater part of the washed material in the Lagarto clays, but these are of course secondary and would not be included when calculating the sorting of the clay samples. The few Oakville clays studied show the same general sizing.

ORIGIN OF THE MIOCENE—PLIOCENE DEPOSITS

The extreme irregularity and lenticularity of bedding, as well as the ripple marks occasionally noted, together with the rapid alternation of clay and sand laminæ or beds in many places, strongly suggests that these deposits are mainly of fluviatile origin. However, the occurrence of glauconite grains in many samples and the presence of a few rather recent foraminifera and marine diatoms lends support to the view that marine waters occasionally covered some of the Oakville-Lagarto sediments at the time of their deposition. The sorting of the sands suggests a fluviatile or delta origin with possibly a considerable addition, locally, of sand brought in by the wind. The beautiful rounding of a small percentage of the grains in contrast to the subangularity of most of them as well as the freshness of many of the felspar grains support the idea that part of the grains were brought in by the wind. These round grains may have been derived from the Catahoula.

The writer believes that the present Oakville-Lagarto portion of the Texas Gulf Coastal Plain during Oakville-Lagarto time was a low flat plain which sloped very gradually to the Gulf of Mexico and passed under the shallow waters of the gulf, probably a few miles southeast of the present Beaumont-Lissie contact. It is an established fact that the Miocene-Pliocene deposits are marine near the present coast line because marine fossils have been found in numerous deep wells near the coast in deposits of this age.

Across this low coastal plain on which the Oakville-Lagarto sands and clays were being deposited meandered numerous rivers and smaller streams. On account of the lack of relief in this plain these streams were continually changing their courses so that they worked back and forth across the whole plain many times during the Upper Miocene and Pliocene epochs thus covering the plain with a thick mantle of medium and fine fluviatile deposits. At the mouths of these streams deltas were probably forming which merged gradually into the flood plain deposits. These deltas probably grew seaward considerably during this time and this was accompanied by a very gradual raising of the land. The delta deposits are thought to have been occasionally subjected to overflow by marine waters at time of high tidal waves, thus mixing a few marine organisms with the fluviatile deposits.

It seems probable that the land back of the Oakville-Lagarto plain was somewhat higher than that back of the Beaumont plain at present. In this way the thick beds of sand were enabled to form, due to the increased velocity of the rivers. It is also possible that the rivers may have been larger at that time. The Cretaceous area of Texas was certainly undergoing active erosion at the time and it is probable that the Balcones folding and faulting was then operative and is responsible for this rapid erosion. In this way the Cretaceous debris has obscured the material derived from the Eocene for the latter had probably suffered much less deformation than the Cretaceous. This would account for the apparent absence of fossil remains derived from the Eocene by erosion in the Oakville-Lagarto sediments.

QUATERNARY SYSTEM

UPPER PLIOCENE?—PLEISTOCENE

LISSIE FORMATION (INCLUDES REYNOSA)

The name Lissie was first given by Alexander Deussen[1] to a series of gravels, sands and clays of probable fluviatile origin Deussen states:

"As here interpreted, the Lissie gravel represents the time equivalents of the middle and lower part (or gravel portion) of the lowest of the three Pleistocene terraces described on pages 82-83.

"The Lissie gravel is believed to represent the coalescing alluvial fans which were spread out at the mouths of the valleys of the streams which discharged into the sea during some parts of Pleistocene time, possibly the early and middle parts."

Another name that has been commonly used to designate the same deposits is "Lafayette" but this term has been applied to deposits of various ages from Cretaceous to Recent, at the type locality it has been found to be part of the Wilcox (Eocene) and it has therefore been discarded as a formational name by the United States Geological Survey. Shaw[2] has discussed this problem.

The writer agrees heartily with Deussen that the Lower (Reynosa) and Upper Lissie are interstream seaward-facing equivalents of the terraces found along the Colorado River and other large rivers of the coastal plain. As previously stated on page 33, river terraces numbers 5, 6, and 7 are thought to be of the same age as the Lower Lissie (Reynosa) while numbers 3 and 4 are correlated with the Upper Lissie. It is doubtful if there was any longer period of time between numbers 4 and 5 than between any of the other two terraces above number 3. There are local unconformities all through the Lissie so that unless an unconformity can be traced almost continuously for some distance it is of doubtful value. No extensive exposures of

[1]Deussen, Alex., Geology and Underground Waters of the Texas Coastal Plain, U. S. G. S. Wat. Sup. Pap. 335, pp. 78-79, 1914.

[2]Shaw, E. W., The Pliocene History of Northern and Central Mississippi, U. S. G. S. Prof. Pap. 108-H., 1918, pp. 1-163.

Lissie were found near the contact of the Lower Lissie with the Upper Lissie. The principal reason generally given for dividing the Lissie into two separate formations is that a number of mammoth and other Pleistocene vertebrate remains have been found in the Upper Lissie and its equivalent river terraces but none have been noted from the Lower Lissie. This is probably mostly due to the better leaching of the Lower Lissie in this region.

General Description.—The Upper and Lower Lissie are so much alike in lithology that one description will serve for both. It might be noted that the gravels in the Lower Lissie are possibly somewhat coarser in general than those in the Upper Lissie and possibly more sand and sandy clay beds occur in the upper portion of the Lissie than in the lower.

The Lissie deposits consist of gravels, sands and clays with almost every gradation between coarse gravel and pure clay. The pure clay is rare, most of the Lissie clays containing a considerable portion of sand and gravel. The deposits containing large percentages of sand and gravel are practically always red, orange, or rusty-yellow in color· although practically all of them contain at least occasional roundish or irregular spots and splotches of pale gray or white. In a few cases the pale gray color is predominant with the red and yellow colors in spots and splotches. Most of the beds in which clay is the principal constituent are pale gray with abundant, very irregular mottlings of red, orange and yellow. Most of the Lissie beds which contain over 50 per cent of clay are more or less characterized by the presence in greater or less abundance, of buck shot-like ferruginous concretions. Some of these concretions also contain considerable manganese in which case they are black in color. Most of the concretions, however, are dark yellowish-brown in color and are composed mainly of limonite. Some contain more or less red earthy hematite. Sand grains and clay are frequently contained in these concretions. The surface of many of the concretions are smooth and shiny but more commonly rather powdery and rough. In diameter the concretions vary from one-half millimeter to four millimeters in general although they are occasionally larger or smaller.

Beds of hard conglomerate with the pebbles cemented together by hard, dark brown limonite and occasionally purplish hematite are common but in general do not exceed two feet in thickness and are usually of local occurrence.

Beds of soft, white sandstone mottled with red occur commonly in the Lower Lissie. The cementing material in this sandstone is clay.

All the limy sandstones, and the occasional limy conglomerates and limestones in Colorado County are placed in the Lagarto by the present author on the basis of lithologic similarity although he recognizes the possibility that the limy conglomeratic sandstone at Tlg 11, which also outcrops along the Colorado River for several miles south of Tlg 11, and the limestone and limy sandstone at Tlg 12 may be Reynosa. However, the writer does not believe that the lower sandstone beds at Tlg 10, which sample is described in detail in Tables 1, 2, 3, and 4, can be Reynosa even if the upper sandstone, described under Tlg 11, should be. The limy phase of the Reynosa which is so prominent farther southwest is not thought to exist in Colorado County with the two possible exceptions mentioned above. "Limy" is used here as containing 15 per cent or more lime, not just a few per cent or a trace. A local thin limy sandstone bed was noted in the Lissie a few miles north of Cheetham and a few more such occurrences may exist but this is rather insignificant. It was associated with typical Lissie gravels.

The author is of the opinion that no good separation of the Lissie into Reynosa and Lissie can be made in this county because they are lithologically too similar and there is rarely a marked topographic break between the two, such as apparently exists in other parts of the coastal plain. If such a separation were made he would draw the line largely on the basis of timber growth and the chert-felspar ratio in the gravel. This division line between the Lower Lissie (Reynosa) Post Oak Belt and the Upper Lissie Prairie can be seen in figure 2, the sketch map showing the topographic divisions of Colorado County.

Uvalde and Reynosa are other names which have been applied to parts of these same deposits.

Parts of the deposits classed by Deussen[1] as Dewitt are in this report included in the Lissie.

In a publication that is still in the press Deussen[2] has abandoned his "Dewitt" formation and divided it into Lagarto (Lower Pliocene) and Reynosa (Pliocene or Lower Pleistocene).

In this report the Lissie formation includes both the Reynosa and Lissie formations of Deussen.[3] The writer's Lower Lissie probably corresponds in general with Deussen's Reynosa, but the Lower and Upper Lissie have not been differentiated on the geologic map. Deussen's[4] contact line between the Reynosa and the Lissie was drawn on the basis of topographic elevation above the Colorado River although he states that no difference in lithology could be noted.

The bedding of the Lissie sediments is extremely irregular, cross-bedding and lenticularity being the rule, so that it is nearly always impossible to obtain even a somewhat reliable dip in these deposits. Local disconformities which show a very irregular surface are common.

The sorting is very poor and variable within surprisingly short distances vertically and horizontally. A bed of coarse conglomerate may lense out into a single row of pebbles within a few feet horizontally. In most of the beds pebbles comprise only a few per cent of the total bed and these pebbles are often strung out in attenuated lines, which are often several feet apart and with only occasional pebbles between them. If the Lissie clays which are apparently free from coarse detritus are washed, nearly always a few rounded pebbles up to four millimeters in di-

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[1]Deussen, *Op. cit.*, pp. 74-78.

[2]Deussen, Alex., Geology of the Coastal Plain Region of Texas, U. S. G. S. Prof. Pap. 126 (still in press).

[3]*Idem.*

[4]Deussen, Alex., Personal communication.

ameter can be found. A photograph of a Lissie clay and sand outcrop is shown in Plate IV, figure 1.

The Lissie deposits are generally characterized by the absence of lime. However, a few beds containing fairly numerous white calcareous concretions from one-fourth to ten millimeters in diameter have been observed. The clays which contain these lime nodules are usually buff and gray mottled with occasional flecks of a red color. A clay containing these concretions was noted on the Columbus-Altair road, about six miles north of Altair and another bed was noted just north of Matthews.

A bed of white bentonitic clay which is splotched with red was traced for two miles along East Sandies Creek, west of Rock Island, Aaron Burleson Survey.

The pebbles in the Lissie sediments are composed of chert, quartz, quartzite, pegmatite, granite, more or less altered volcanic rocks, silicified wood, chalcedony, schist and slate. Their composition will be discussed more fully under "Petrography of the Lissie."

In shape these pebbles vary from rather sharply angular to well-rounded but the majority are probably subrounded. They vary in size from 25 centimeters down in diameter. Most of the larger pebbles are brown or gray chert or flint.

Sections.—Most of the sections of Lissie consist of alternating argillaceous sands and gravels which grade into one another. The bedding is not well marked and is irregular so that a detailed section is not of much value. Very few places were seen where more than 15 feet of Lissie is exposed.

The section on the west bank of the Colorado River at Garwood is as follows:

SECTION OF WEST BANK OF COLORADO RIVER ONE-FOURTH MILE NORTH OF GARWOOD

Beaumont:

1. Black jointed clay soil.. 1′ to2′
2. Jointed and cracked, magenta-red, massive, calcareous clay containing a few calcareous concretions.... 2′ to 4′

Unconformity?

Lissie (possibly Beaumont):

3. Pale yellowish to pinkish, slightly calcareous, medium-grained, loose sand, which is greatly cross-bedded and contains near the middle of the bed a thin layer with pinkish calcareous concretions up to 3 centimeters in diameter............ 8′

Lissie:

4. Brownish-red to orange, medium-grained, arenaceous and argillaceous, non-calcareous gravel containing a number of large rounded clay lumps............ 2′ to 3′
5. Coarse, cross-bedded, gravelly sand with a few streaks of slightly calcareous red clay............ 5′
6. Sandy gravels with pebbles up to 2 inches in diameter and a few lenses up to 8 inches thick of brownish-red, laminated clay, to water's edge at low stage............ 6′

Total............ 28′

The thickness of the lower four beds varies from place to place.

Dip and Thickness.—No estimation can be made on the dip of the Lissie from surface outcrops, except that it is southeast at a very low angle. The dip of the Lissie, based on its contact with the underlying Lagarto as determined from two wells in the southeastern portion of Colorado County and across the line in Wharton County, is approximately 12 feet per mile. One of these wells is located three miles south-southwest of Eagle Lake and the other one mile south of Lissie, Wharton County, which is two miles across the Colorado County line. The wells are approximately seven miles apart, measured at right angles to the strike, and the more southeasterly well passed through 81 feet more of Lissie than the northeasterly well. The surface elevation of the two wells is very nearly the same. However, there is a marked unconformity at the base of the Lissie, so this dip may not be an average.

The Lissie in Colorado County, so far as can be told from the few well logs that are available, is not over 300 feet thick at any place in Colorado County. However, the whole section of Lissie is not present anywhere in this county and the Lissie probably thickens considerably to the southeast. There is every variation in the thickness of the Lissie in Colorado County from a few inches in the western and northern part of the county to three hundred feet in the eastern portion.

In the Schaffner No. 1 well, at Red Hill in Austin County, the Lissie appears to be between 262 feet and 300 feet thick although this well is considerably nearer to the Lagarto outcrop than either the Eagle Lake or the Lissie wells. The description of the sample from 262 feet, which was made by Miss Hedwig Kniker, sounds much more like Lissie than Lagarto. The next description, that from 360 feet, is undoubtedly Lagarto so the contact line is between 262 and 360 feet.

Distribution.—As shown on the geologic map in the pocket, the Upper and Lower Lissie cover over two-thirds of Colorado County at the surface. The Lissie forms a continuous belt from Frelsburg, Columbus and Shimek south and southeast to the Wharton, Lavaca, and Jackson County lines with the exception of a relatively small area in the vicinity of Garwood, the second and first bottoms of the Colorado River and the disconnected outcrops of Lagarto previously noted. Most of the northern part of Colorado County in the vicinity of the Colorado River and between the river and Cummins Creek is also covered at the surface by a veneer of Lower Lissie.

The main contact of the Lissie with the underlying Lagarto clays extends as a rough semi-circle from near the point where the M. K. & T. Ry. crosses the northeast county line to the Lavaca County line near Shimek.

Lissie in Wells.—Miss Kniker's description of the two Lissie samples from the Schaffner No. 1 well are as follows:

"Gray and red calcareous clay. Washed material consists of poorly sorted, pink sand and a few calcareous concretions. Most of the sand is less than three-fifths millimeter in size. The grains are subangular and polished and most of it consists of clear quartz. Some grains are stained red by iron and a small amount of gray chert gravel is present—200 feet.

"Red sandy clay with white calcareous concretions and some small clay ironstone concretions. The sand is like that from 200 feet, but slightly coarser—262 feet."

Paleontology.—In the Lower Lissie (Reynosa) and its equivalent river terraces, numbers 5, 6, and 7, no fossils were found except a few partly eroded silicified Cretaceous oyster shells and a few small, unrecognizable, eroded bone fragments mostly under three inches in length.

In the Upper Lissie gravels near the base of the river bank at Garwood most of a proboscidian skull lacking the teeth and lower jaw was found. At Horton and Horton's gravel pit in number 3 river terrace, one mile southwest of Columbus, several mammoth teeth and bone fragments were found by men working in the pit. These were in the possession of Mr. O. A. Zumwalt who kindly presented some of them to the Bureau of Economic Geology and Technology. One of the teeth was identified as *Elephas columbi*, the Columbian mammoth, by Dr. E. H. Sellards but another which is still in the possession of Mr. Zumwalt is probably that of the great *Elephas imperator*, the imperial mammoth. Tusks, bones and teeth of these mammoths were reported to have been found in other parts of the same terrace. These prove that this terrace and the Upper Lissie as a whole is of Pleistocene age.

Silicified and eroded Cretaceous? oyster shells have also been found in the Upper Lissie near Rock Island.

The age of the Lower Lissie (Reynosa) is uncertain because no fossils of stratigraphic value have been reported from these beds so far as the writer is aware. It is possible that a very thorough search including many excavations might yield determinable vertebrate fossils. From its great similarity to the Upper Lissie, which would seem to indicate a similar climate throughout the deposition of the two portions of this formation, the writer is inclined to regard the Lower Lissie as Pleistocene also, probably earliest Pleistocene. It is of course possible that the lower part of the Lissie (Reynosa) is of uppermost Pliocene but a big break certainly exists between the uppermost Lagarto and lowest Lissie.

Petrography of the Lissie.—Eight samples, representing characteristic phases of the Lissie were studied in detail and their minerals and rocks identified under the petrographic microscope. The characteristics of these samples are summarized in tables 1, 2, 3, and 4, pages 84-90,. In these tables, Stations Ql 2, 3, 4, and 5 are in the Lower Lissie and Ql 6 and probably Ql 1 are in the Upper Lissie. It is possible that Ql 1 may also be in the Lower Lissie

The "Average Lissie" samples given are not mere averages of the few samples studied. The samples studied were not very large and very few or none of the larger pebbles were included in a given sample. These larger pebbles are almost always composed of gray flint or chalcedony which is stained yellow-brown on the outside and if account is taken of them the amount of chert present and the percentage of coarse separates is considerably increased. The texture of the gravel varies so greatly from place to place that it would take a prolonged and careful study to arrive at a true average but the averages given are thought to be fair approximations. Mechanical analyses on a number of gravel samples are found in Table 5, opposite p. 134.

Mineral Composition.—Some field studies made on Lissie gravels for the purpose of ascertaining how many different rock types are represented in the pebbles in these deposits are given below. These studies were made with a hand lens.

Gravel from Old Gravel Pit on Fourth River Terrace One Mile West of Columbus Near Highway.—This is typically an orange-red unconsolidated sandy gravel. Some beds contain a considerable amount of iron-stained clay in the matrix which locally has whitish or pale greenish splotches and streaks or may be distinctly mottled red and pale green.

Matrix of Gravel.—The matrix is composed of mostly angular or subangular sand grains (averaging about one-fourth millimeter in diameter) which are coated by thin films of reddish clay or iron oxide. These sand grains are composed largely of translucent or transparent and whitish quartz and gray and pink chert. The films of clay are sometimes fairly thick.

Pebbles.—These vary in size from 15 centimeters to coarse sand in size but the average is about seven millimeters although certain strata contain much more gravel and the average size is much larger. However, not many pebbles occur in this deposit which are over six centimeters in diameter. The average pebble is subrounded although occasionally very well rounded ones are seen. Many subangular pebbles are also present.

They are composed of (1) chert (gray, yellowish, black, red, pink and greenish)—abundant; (2) quartz (transparent, white, or yellowish)—common; (3) pegmatite (pale pink rock composed mostly of felspar but with minor amounts of quartz and biotite)—common; (4) volcanic rock fragments, mostly rhyolite and basalt? (all more or less altered and silicified and varying from red to greenish gray and black)—frequent; (5) quartzite (very hard and dark red in color)—uncommon; (6) granite (pale pink and composed of quartz, pink felspar and biotite)—uncommon; (7) sandstone (yellowish-gray and cemented with silica)—uncommon; (8) amphibolite schist (dark greenish-black and composed mainly of fibrous hornblend—rare; (9) quartz—tourmaline rock (composed of igneous quartz and black columnar tourmaline, evidently derived from a pegmatite dike)—very rare.

Several of the chert grains are deeply pitted and some were oolitic. The pitted pebbles were evidently cherty limestone originally but no lime is left in any of them at present. Probably most of the chert was derived from the cherty Edwards and other Cretaceous limestones. Some of the chert pebbles are composed of almost pure waxy opal. The sandstone may have come from the Catahoula or Eocene. The remaining rocks resemble types seen in the Central Mineral Region and are evidently derived from that source.

Gravel from the Summit of Rocky Hill, Three Miles Southwest of Glidden on Terrace Number 6.—These Lower Lissie deposits, a photograph of which is shown in Plate IV, figure 2, consist of gravels, sands, and a few thinner beds of sandy clay. The gravels are thoroughly oxidized and stained with iron throughout. The pebbles vary in size from boulders 30 centimeters in diameter down to sand. The average sized pebble is about six to nine centimeters in diameter, but cobbles of larger size are common. Many of the larger boulders have been hauled off for ballast. The purer gravel beds like the other beds are lenticular.

The sands are always more or less mixed with clay and vary in color from white to deep red, often being mottled with splotches of red and white. Thin streaks to well developed gravel beds occur in the midst of sandy beds. Sands are greatly cross-bedded, some of the individual laminæ dipping as much as 30 degrees. Balls or lumps of whitish clay are often imbedded in the sands. The sand grains are fairly angular and mostly coarse. They are usually surrounded with films of clay which occasionally become fairly thick.

Composition of the Pebbles.—Fully 90 per cent of the pebbles and cobbles are chert, from gray to yellow-brown and jasper-red in color. Most of the remainder are composed of whitish, yellowish, and pink quartz most of which seems to be of secondary (vein) origin. A number of pebbles of beautifully banded silicified wood are present. A few very light, porous, whitish pebbles which resemble limestone were noted. However, these will not effervesce in the slightest when treated with hydrochloric acid and are composed of a minute-grained argillaceous material which is apparently held together with siliceous cement.

The older terrace gravels (Lower Lissie) in general seem to contain far less pegmatitic, granitic, schistose and quartzitic pebbles, but they cannot be distinguished surely in this manner because at a few places in the Lower Lissie igneous (especially pegmatitic) pebbles are common.

A close search was made for limestone pebbles but no pebbles containing lime were found in either the Upper or Lower Lissie. Completely leached pebbles that were originally limestone are fairly frequent but not at all common.

Minerals of the Lissie—Light Minerals.—The two principal minerals in the Lissie gravels are chert and quartz. The majority of the pebbles in most samples are chert but quartz is much more common in the sand grains. The chert is of various colors, brown, gray, white, red, black and green and both igneous and vein quartz are common. Probably vein quartz is much the commoner in the Lower Lissie and igneous quartz in the Upper Lissie. The vein quartz is often stained yellowish and pinkish and is full of small cracks so that pebbles of it are opaque. In table 4, silicified wood has been included under chert. However, much less than one per cent of the chert is silicified wood.

More or less iron stained clay is always present in the Lissie gravels and this substance often makes up a considerable percentage of a gravel sample. This clay is composed of kaolinite, iron oxide, more or less mica and chlorite flakes and numerous small grains of quartz, felspar and a few other minerals. Most of the soft sandstones in the Lissie are cemented with argillaceous material, but some opaline material is occasionally present.

Felspar, mostly of a pink or flesh color, and coarse grained pegmatite which usually contains more felspar than quartz are some of the principal constituents present in many of the gravels and sands of the Lissie. Orthoclase is the commonest felspar but pink microline is also common. White to colorless plagioclase is frequent.

Leverrierite? was found in one sample, Ql 5, Number 2. In fact probably 70 per cent of this white and red mottled bentonite-like clay was composed of leverrierite. The index of refraction of most of the sample was below 1.53 and this index was raised considerably on leaving the mineral standing in oil for two weeks. This sample also slakes beautifully and extremely rapidly into a flocculent doughy mass on putting a piece of it in water. This is unlike any of the other clays found in the Lissie and is thought to represent a very finely comminuted volcanic dust bed which has been mixed with a few sedimentary grains. No volcanic glass grains could be found in this sample so as to check this conclusion, but this is probably due to their being so small that all have altered completely to leverrierite. This bentonite-like clay underlies a bed of argilaceous Lissie sandstone and it grades into this sandstone as would be expected of a volcanic dust deposit. The source of the dust must have been quite distant. This bed of bentonite is fully ten feet thick and the base was not seen. It was traced down East Sandies Creek for a mile and may extend farther. This occurrence of volcanic debris in the Texas Coastal Plain Pleistocene is a new observation. Volcanic dust has been observed in the middle of the Rock Creek (Pleistocene) beds on the north side of Tule Canyon near the border of Briscoe and Swisher counties but its source must have been from the Rocky Mountain volcanoes.[1]

Calcite is rather rare in the Lissie but calcareous concretions have been noted in a few beds in the Lissie clays. Chalcedony grains and pebbles are frequently present in negligible quantities in the Lissie. Of course much of the chert is composed partly of chalcedony.

Heavy Minerals.—The minerals of high specific gravity are relatively much more abundant in the Lissie than in any of the other Colorado County formations.

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[1]Baker, C. L., Geology and Underground Waters of the Northern Llano Estacado, Univ. of Tex. Bull. No. 57, p. 35, 1915.

By far the greatest part of the "heavy" minerals is composed of oxide of iron both in concretionary and disseminated form. Most of this iron oxide is in the form of limonite although hematite and magnetite are common. More or less manganese oxide is often mixed with the limonite in the ferruginous concretions and also in the limonitic matrix of the hard conglomeratic lenses. This manganese oxide is probably psilomelane.

The other heavy minerals occurring in the Lissie are present in negligible amounts. These are actinolite, apatite, biotite, cassiterite?, chlorite, epidote, garnet, hornblend, ilmenite, kyanite, monazite, muscovite, rutile, titanite, tourmaline, tremolite, and zircon. Of these the most common are hornblend, garnet and tourmaline, but no distinctive characters peculiar to this formation were noted in any of these minerals.

Lime Content.—The Lissie is very low in lime, which is almost entirely absent from the great majority of samples.

Rounding of Grains.—The majority of the pebbles are subrounded to subangular, although the felspar and pegmatite pebbles are often rounded-rectangular. Most of the smaller pebbles are subangular while most of those over five centimeters in diameter are subrounded, at least that is apparently the case. It is noteworthy that the largest pebbles are usually the best rounded.

The sand grains are prevalently subangular but most of them below one-fourth millimeter are angular. Probably from five to ten per cent of the grains in an average sand are subrounded. A small number of grains are beautifully rounded and polished.

Sorting.—As would be expected of fluviatile alluvial fan deposits the sorting of these sediments is very poor, in fact many of these deposits are almost unsorted.

Three maxima are often present in the gravels. These maxima are frequently from 32 to 16 millimeters or above 32 millimeters, one to one-half millimeter, and below one-sixteenth millimeter, but maxima may frequently come in other separates.

Two maxima are apparently the rule in the Lissie sands and sandy clays. One of these maxima is always below one-sixteenth millimeter. The other is more often from one-half to one-fourth millimeter, but one to one-half millimeter and one-fourth to one-eighth millimeter may be the maximum sand separate.

ORIGIN

It is the opinion of the writer that the Lissie (and Reynosa where this is typically developed in the Texas Coastal Plain) have a common origin. This is thought to be intimately connected with the widespread glaciation that was going on in the northern part of North America at the time of the deposition of the Lissie-Reynosa.

It is recognized by several of the writers who have described the Lissie-Reynosa (Lafayette) deposits that these sediments are terrace gravels of fluviatile origin. The present writer sees no logical escape from the idea that the gravels were brought down by rivers and some of these rivers must have been very large and possessed swift strong currents in order to carry the ten-inch boulders that are occasionally found so far from their source in the Cretaceous rocks of Texas.

There is more or less gravel in the bed of the Colorado River at present but most of this has fallen from cliffs composed of old terrace gravel. No instances of gravel bars in the river or gravel deposits on the present flood plain of the river are known to the writer anywhere in the Colorado County region. However, thick gravel deposits (often coarse) are found along practically all the large streams and in many interstream areas all the way from the Balcones escarpment to the Lissie-Beaumont contact which often comes within fifty miles of the coast. This gravel veneer has been mainly eroded from the interstream areas as far downstream as Columbus, Hempstead, etc., and possibly was never deposited on some of the higher interstream areas north of these towns. However, it seems that a considerable part of the Texas Coastal Plain has been covered (and to a certain extent still is covered) with a thick or thin veneer of terrace gravels. This veneer or alluvial apron is progressively thicker to the southeast. It is thought that in Pleistocene and possibly uppermost Pliocene times the area now covered continuously at the surface with Lissie-Reynosa and Beaumont deposits was a fairly flat practically featureless plain having lower elevation in respect to the present sea level than it has now so that a river flowing out onto this plain from a region of relatively greater relief would drop most of its load in this area.

The territory upstream from the base of the Reynosa-Lissie had been raised up since Middle or Lower Pliocene time, as shown by the extensive unconformity at the base of the Lissie-Reynosa, and was undergoing erosion in Pleistocene and Upper Pliocene times. This upraising and the subsequent erosion had caused the stream beds to have a fair gradient to the southeast.

Owing to the extensive ice-caps in the northern United States and Canada the climate of Texas,, like that of the Great Basin in the West, was cooler and probably more humid than at present. It is possible that some of the Texas streams received additional water from the melting of glacial ice near their sources. In any case with this climate the streams must have been considerably larger and therefore much more efficient eroding and transporting agents than they are at present. This would account for the coarse gravel deposits which are found so far southeast.

When these overloaded streams reached the above-mentioned low plain they would naturally dump all their debris except some of the very finest which was carried on out to sea. Their channels would continually be getting clogged with the result that the streams would be always changing their channels. In this way during the long Pleistocene epoch they could change their channels and flood plains back and forth so that these alluvial fan deposits would become continuous alluvial aprons, such as are found at the base of some of the steep mountain ranges of the west today.

If there were a distinct escarpment near the present base of the Lissie-Reynosa in Pleistocene-Upper Pliocene? times with a flat plain at its base a similar result might have been obtained but the existence of such an escarpment is unlikely and this theory would not explain the common covering of interstream areas with this gravel many miles upstream. Therefore the first hypothesis is considered more likely.

Some authors have considered the Lissie-Reynosa (Lafayette) or part of it to be formed at the coast line, that is, that they are delta deposits. The complete absence of marine fossils and the presence of land vertebrates at many localities in the Upper Lissie makes the land origin much more probable.

It seems probable that the Balcones faulting, which can not be very ancient because its scarp is so well preserved, took place just previous to and probably in part during Lissie-Reynosa time. The erosion of the newly formed scarp and the elevated terrain back of it would furnish many chert and flint pebbles. Also this great alluvial apron of gravel seems to have its northwestern boundary near the Balcones scarp. Just after this faulting the grades of the streams would be very high and this together with their probable greater size on account of the moister Pleistocene climate would enable them to carry much gravel and even large cobbles and boulders.

PLEISTOCENE

BEAUMONT FORMATION

The Beaumont clay is of Middle and probably partly Upper Pleistocene age. It is equivalent in age to the second river terrace. As is the case with the Lissie the second river terrace, or Garwood terrace, grades into the seaward-facing Beaumont terrace which forms a broad strip of black land between the seaward side of the Upper Lissie terrace and the recent deposits along the coast. This merging of the second Colorado River terrace into the seaward-facing Beaumont terrace takes place in southeastern Colorado County, for the strip of black land in the vicinity of Garwood stretches without break to El Campo in Wharton County and on to the coast.

General Description.—The Beaumont in Colorado County consists of deep red and dark grayish-brown calcareous clays which weather to a black soil. These clays all contain more or less white calcareous concretions up to three centimeters in diameter and considerable organic material. There are also some fairly thick beds of medium-grained, pale buff, slightly calcareous, fairly well sorted sand which may be either Beaumont or Upper Lissie. There is apparently a disconformity at the base of the Beaumont as shown by the variation in thickness of Number 2 and its weathered portion, Number 1, in the section at Garwood given on page 101. This contact is too much obscured by slumping for one to be sure of the disconformity. There is certainly a very marked break in type of sediment. The disconformity, if such exists, is not thought to represent a very long period of time because Pleistocene fossils are found both in the Lissie and Beaumont and much of the Pleistocene must be represented in such thick deposits as these two formations. Very few exposures of unweathered Beaumont can be seen in Colorado County on account of the flatness of the county in the region of its outcrop.

The second terrace or bottom of the Colorado River farther upstream, notably just south of Columbus in the river bank is a gravelly and sandy silt containing a great abundance—in places 20 per cent—of land snails and fresh water mussels, *Unio*. The pebbles in this deposit are rather scattered and of the same types found in the Lissie. They have evidently come from the Lissie (third terrace), which is close at hand.

Distribution.—The second terrace of the Colorado River which is of Beaumont age, is developed at many places along the river in Colorado County, but this terrace is mostly rather narrow and often thickly wooded and unlike the typical Beaumont prairie south of Altair. However, south of Altair this terrace becomes progressively wider and is mainly a featureless black-land prairie like the typical Beaumont nearer the coast. On the geologic map no attempt has been made to differentiate the Beaumont terrace from the first bottom or flood plain north of Altair. This has been done south of Altair. The bed of Caney Creek which drains Eagle Lake is thought to be younger than the Beaumont, and the Beaumont is therefore separated into two portions by this more recent alluvium which marks the old channel of the Colorado River.

Dip and Thickness.—The dip of the Beaumont is southeast at a very low angle, probably about 10 feet to the mile. The formation is probably nowhere over 30 feet thick in Colorado County.

Paleontology.—No fossils except shells of land snails and fresh water mussles, *Unio*, Chara stems, and a few tiny foraminifera have been noted in the Beaumont clay in Colorado County. The foraminifera were: *Globigerina, Textularia* and *Truncatulina* and may be secondarily derived from the Cretaceous. However, about nine miles south of Garwood on the Johnson-Pryor Ranch in Wharton County, 24 feet from the top of the Colorado River bank, a number of mammoth bones and teeth were dug out of the Beaumont red clay. These were discovered several years ago and most of the remains were presented to the Bureau of Economic Geology and Technology by Mr. August Ilse of Columbus and the Nada Drug Company of Nada. The bones were from *Elephas imperator*, the imperial mammoth.

Petrography of the Beaumont.—Two samples of the Beaumont red clay were studied under the petrographic microscope. One of these (Qb 1) is from the red clay exposed at the top of the Colorado River bank at Garwood. The other (Qb 2) comes from the *Elephas imperator* locality in Wharton County, nine miles south of Garwood. These two samples are very similar. A summary of the characteristics of these samples is found in Tables 1, 2, 3, and 4.

Minerals of the Beaumont: "Light" Minerals.—Clay comprises four-fifths or more of both samples and of the Beaumont clay in general. This clay probably consists mainly of kaolin, although possibly one-fifth of the so-called clay consists of tiny silt grains of quartz, mica, chlorite, and felspar. Calcite is the next most abundant substance in the Beaumont clay. Most of it is in very fine disseminated particles but concretions of calcite up to six centimeters in diameter are abundant also. Most of the sand washed out of the Beaumont clay consists of transparent and grayish quartz grains. Black, brown and gray chert and felspar comprise about 10 per cent of the washed material from the clay samples. Most of the felspar is more or less altered orthoclase, but microcline is also quite prominent. Plagioclase is rare. No other "light" minerals were observed.

"Heavy" Minerals.—Most of the red stain in the clay is attributed to hematite although it may be limonite or some of the other hydrous oxides of iron. The one per cent of hematite noted in Table 4 is this red staining material. Limonite is also frequent as a staining material on sand grains. Magnetite, biotite, muscovite and dark green hornblend are the commonest heavy minerals outside of the staining material. The prominence of hornblend is possibly noteworthy in these samples.

Other heavy minerals occurring rarely are zircon, tourmaline, epidote, apatite, barite, cassiterite?, and titanite.

Shape of Grains.—Most of the sand grains below one-fourth millimeter are subangular to angular. However, possibly a third of the sand grains above one-fourth millimeter are rounded and subrounded. The well rounded grains are mostly transparent quartz.

Lime Content.—The sample of Beaumont (Qb 1) from Colorado County contains 12.43 per cent of calcium carbonate in a chemical determination made. The sample from Wharton County contains a somewhat larger percentage of lime and more concretions of lime.

Sorting.—Probably at least 95 per cent of the Beaumont clay grains are below one-sixteenth millimeter while usually the sand grains are between one-fourth and one-sixteenth millimeter. A few sand grains up to one millimeter were noted. All the washed material above one millimeter consisted of calcareous concretions.

ORIGIN

The Beaumont clay is thought to represent mainly a delta deposit although possibly a considerable part of it was deposited on the outer edges of the alluvial plain built up by the Lissie deposits. The preponderance of clay material in the Beaumont is best accounted for by flocculation due to the muddy waters of the swollen Pleistocene rivers and smaller streams coming in contact with the salt water of the Gulf or brackish waters of lagoons bordering the Gulf. The gradient of the streams had apparently been flattened out by the deposition of the Lissie so that they could not carry much sand as far as the present Beaumont outcrop. Brackish water shells have been found in the Beaumont nearer to the coast. It is probable, however, that the Beaumont in Colorado County has never come in contact with the waters of the open Gulf, although a Pleistocene lagoon may have extended up as far as Garwood. The abundance of finely comminuted vegetable matter as well as the character and geographical occurrence of the sediments support the delta origin.

SMALLER PLEISTOCENE TERRACES

Many of the smaller streams in the northwestern two-thirds of Colorado County, especially in the area of the Lagarto outcrop have developed as many as three well marked terraces.

General Description.—The material of which these terraces is composed often resembles the underlying geologic formation in the region. This is especially well marked in the Lagarto terrain where some of the terrace material is almost identical in appearance to the underlying Lagarto clay from which the terrace has been largely derived. However, this terrace material is generally considerably more sandy and shows poorer sorting than the Lagarto clay. It contains no sandstone beds or lenses like the Lagarto does in most places. Pleistocene proboscideans, both mammoth and mastodon, have been found at several places in the vicinity of Weimar in these smaller stream terraces.

In the Lower Lissie (Reynosa) terrain the small stream terrace material generally resembles the sandy clays of this formation and often contains a few pebbles of flint and quartz but no distinct gravel layers are present. In color it is mostly pale buff and gray with red splotches here and there. It frequently contains both ferruginous and calcareous concretions and may be stained with manganese in the joint planes.

About one mile northeast of Oakland there is a peculiar deposit which is about 10 feet thick and whose outcrop occupies several acres of ground. This is a dark grayish-blue sandy loam or sandy clay which is packed full of thin-shelled land snails, pulmonates. This apparently marks the site of a small Pleistocene lake that has been filled up and the deposits which formed on its bottom have now been dissected by erosion.

Paleontology.—A large number of mastodon teeth and a few mammoth teeth, as well as fragments of the tusks of these animals have been found in the terraces of the various forks of Harvey Creek in the vicinity of Weimar. These fossil localities are marked on the geologic map. One of the tusks dug out of this terrace material by the writer was nine inches in diameter near the center and must have been fully five or six feet long originally. Most of these mammoth and mastodon teeth were discovered by Mr. Frank Janecka, who lives two miles northeast of Weimar.

The terraces containing these remains are thus proved to be of Pleistocene age, or equivalent to the Upper Lissie and Beaumont.

RECENT

In geologically recent times, after the deposition of the Beaumont terrace and delta deposits there has evidently been a slight uplift of the land which allowed the present rivers to cut their channels as much as 25 feet below the Beaumont or second terrace level.

ALLUVIUM

General Description.—The present flood plain of the Colorado River in Colorado County is built up mainly of dark reddish-brown silty clay, often containing a considerable amount of mica. These recent deposits are often laminated or more or less banded and are sometimes cross-bedded. They are frequently fairly calcareous and sometimes contain small calcareous concretions which are hollow and probably still in the process of formation. Ferruginous concretions also can be washed out of this silt or clay. The rapidity with which these concretions form is thus shown and seems rather surprising. These concretions are not ordinarily observed until the sample is washed.

Dip and Thickness.—The recent river alluvium dips one or two feet to the mile southeast, which is the approximate grade of the Colorado River at present. It reaches a thickness of possibly 25 feet in places but is generally thinner.

Paleontology.—Land snails, *Unios,* dead leaves, twigs, logs and other vegetable and fresh water mollusk remains are common in this recent alluvium. A few bone fragments probably of American buffaloes were noted eight feet below the surface in a ditch made in the bed of Caney Creek, one mile northwest of Matthews. This broad channel like depression through which Caney Creek formerly flowed before the waters were diverted for irrigation purposes is thought to represent the old bed of the Colorado River.

Petrography.—Only one sample of first bottom alluvium collected near Station Tlp 3 was studied in detail. This sample consists of about 95 per cent of fine silt and clay with clay probably predominant. Of the five per cent left after washing out the finest material at least two-thirds consists of calcareous concretions. A limonitic concretion was also present.

Most of the true sand grains are between one-eighth and one-sixteenth millimeter in diameter and the coarsest sand grain noted was about one-half millimeter in diameter.

The minerals noted in the washed material are given in their order of abundance as follows: (1) calcite (concretionary); (2) quartz; (3) limonite (concretionary); (4) chert; (5) felspar; (6) muscovite; (7) hornblend; (8) muscovite; (9) magnetite; (10) zircon. The first three minerals are far more abundant than the others. Practically all the sand grains noted were angular.

SUMMARY OF THE PRINCIPAL CHARACTERISTICS IN COMPOSITION OF THE FORMATIONS IN COLORADO COUNTY*

Characteristics of the Frio (Jackson).—The Frio consists very largely of clay of a black, gray, pink or green color. The black clay is non-calcareous and contains indigenous marine fossils. This is the youngest formation in the Colorado County region that contains abundant marine fossils which are not mainly derived from the Cretaceous. Black clay has not been noted above the Frio.

The characteristic fossils noted are fragments of Upper Eocene pelecypods and gastropods, the foraminifera, *Bolivina robusta*(?), *Nodosaria* cf. *consobrina* var. *emaciata, Polymorphina* and *Cristellaria,* ostracods and echinoid spines. *Bolivina* is abundant.

Much of the clay contains an abundance of leverrierite (hydrated volcanic dust), which causes it to slake quickly in water. The sand washed from the Frio clay shows a characteristic abundance of more or less altered volcanic

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*The data given below are based on the microscopic examination of a comparatively small number of surface and well samples and are therefore only tentative. It is hoped that this summary may be useful to sub-surface and field geologists in spite of the incompleteness of the data.

glass, plagioclase and orthoclase felspar in nearly equal amounts, and prisms of aragonite. Splinters of bluish chalcedony are frequent and are rarely found in the overlying formations. Lignite is more abundant in the Frio than in any formation above.

Characteristics of the Corrigan.—The Corrigan in this region is composed of clay with minor intercolations of rather fine-grained sands and sandstone. Most of the clay is pale yellowish-green in color and is non-calcareous but contains scattered small calcareous concretions. Only about two per cent of the sand grains are rounded, which is very much lower than the percentage of rounded grains from the outcropping Catahoula sandstone farther east. The non-calcareous character of most of the Corrigan clay from the wells in Colorado County may serve to distinguish it from the overlying Oakville.

The only fossils that have been found in the Corrigan which apparently lived in Corrigan time are rather rare Chara fruit. Foraminifera (probably derived from the Cretaceous) of the genera *Globigerina, Cristellaria, Textularia* and *Anomalina* are rare. Ostracods are also noted rarely. The Corrigan seems to be characterized in this area by an extreme scarcity of any organisms.

The noteworthy abundant minerals of the Corrigan are orthoclase and plagioclase felspar and gray and yellow chert. Very little pink and black chert, so common in the Oakville and Lagarto sands, is found in the Corrigan. Microcline felspar seems to be absent from the Corrigan but is very common above it. Lignite occasionally occurs in the Corrigan.

Characteristics of the Oakville.—The Oakville is apparently much more argillaceous, where it underlies other formations in Colorado County, than where it outcrops. The Oakville clay is mainly creamy-gray to pale greenish-gray in color and some of it is bentonitic. It is very difficult and often impossible to distinguish Oakville sands and sandstones from those of the Lagarto. Practically all the Oakville rocks here are strongly calcareous and this feature is unlike the Corrigan. Some beds of sandy tuff or volcanic ash occur.

Land vertebrate bones and bone fragments are more common in the Oakville than in the Lagarto. Chara stems are fairly common. Tiny spore-like bodies and disc-shaped diatoms are rare. Eroded shells and fragments of shells derived from Cretaceous sediments are often abundant in the coarser Oakville sandstones. Small foraminifera, also mainly derived from the Cretaceous, are abundant in many beds. The genera *Textularia, Globigerina* and *Anomalina* are the commonest genera represented.

The only mineralogical differences between the Oakville and Lagarto that were noted, are the frequent occurrence of more or less altered volcanic glass prains and the alteration product, leverrierite, and the apparent absence of manganiferous concretions and dendrites and of strontionite in the Oakville. Mineralogical characteristics that are common to both Oakville and Lagarto, are the abundance of black and pink chert grains, honey-yellow chalcedony, pink orthoclase and microcline felspar. Plagioclase felspar is comparatively uncommon. Minerals occurring in small amounts in the Oakville and Lagarto but not in overlying formations, are glauconite, pyrite, and gypsum.

Characteristics of the Lagarto.—Two-thirds of the Lagarto consists of calcareous clay which is usually pale gray mottled with buff. In the lower part, the Lapara member, beds of pale green and pink mottled clay which are not so calcareous as the rest of the Lagarto clay, occur. The calcareous sandstones and sands of the Lagarto are similar to those of the Oakville.

Nearly all the fossils found in the Lagarto clay, with the exception of fairly common Chara stems and rare land vertebrate bone fragments, seem to have been derived from the Cretaceous. The secondarily introduced fossils are more or less eroded Cretaceous pelecypods or fragments of pelecypods and gastropods and numerous small foraminifera. The common genera of foraminifera noted are *Textularia, Globigerina* and *Anomalina.*

The minerals which seem to occur in the Lagarto and not in the Oakville are only manganiferous concretions and dendrites and occasional strontianite prisms and veins.

The minerals occurring in characteristic abundance in both Lagarto and Oakville are black and pink chert, honey-yellow chalcedony and pink orthoclase and microcline felspar. Plagioclase is only frequent. Glauconite, gypsum and pyrite, which are present sparingly in the Lagarto and Oakville have not been noted above the Lagarto.

Characteristics of the Lissie.—The Lissie consists mainly of more or less conglomeratic non-calcareous argillaceous sand or arenaceous clay. Thick beds of gravel occur. The Lissie rocks are generally orange-red in color or mottled gray, red and yellow. Most of the large pebbles in the Lissie are chert. Only minor beds of conglomeratic sandstones are found in the Lagarto. The non-calcareous or very slightly calcareous character of most of the Lissie at the surface is often sufficient to distinguish surface exposures of it from Lagarto and Beaumont. In well samples calcareous concretions are frequently reported from the Lissie, however. The extremely poor sorting of the Lissie is often distinctive. One bed of white, nearly pure bentonite occurs near the middle of the Lissie.

A few large land vertebrate remains are sometimes encountered in the Lissie. The only other fossils seen are eroded Cretaceous pelecypods or their fragments.

The distinctive minerals or rocks found in abundance in the Lissie are chert of all colors, vein quartz, red and orange iron oxide stain, limonite concretions, pink pegmatite, granite and red quartzite. Hornblend and tourmaline are found in traces but are more common here than in the Lagarto and lower. Calcite is rather rare in the Lissie.

Characteristics of the Beaumont.—The Beaumont consists of magenta-red and brownish-gray calcareous clay. It contains more disseminated organic (plant) matter than the Lissie or Lagarto. Only a little sand occurs in the Beaumont in this area. The Beaumont contains less lime than the Lagarto in general.

The fossils of the Beaumont are wood fragments, Chara stems, occasional large land vertebrate remains, land snail or pulmonate shells, *Unio* shells or fragments of them, and frequently small, probably secondarily introduced Cretaceous (at least in part) foraminifera of the genera *Globigerina* and *Textularia.*

The low percentage of felspar and chert and the consequent higher percentage of quartz are noteworthy. Most of the chert and much of the felspar is gray in color. Green hornblend occurs more commonly in the Beaumont samples seen than in any other formation studied in this region.

STRUCTURAL GEOLOGY

The main geologic structure of Colorado County, like that of most of the Gulf Coastal Plain, is a gentle southeastward dipping homocline. That is to say, the general underground structure of Colorado County consists of a series of sedimentary beds all of which dip in the same direction, namely southeast. This type of structure is often called monoclinal but homoclinal is a more appropriate term. The dip of the formations at the surface becomes progressively gentler from the northwest to the southeast depending on the geologic formation exposed. The Lagarto rocks have a considerably steeper dip than the Lissie and Beaumont, but none of these beds are thought to dip much over 60 feet to the mile or a little over one-half a degree. We therefore see that the general structure of this county is extremely simple.

No faults have been noted in the county, although some of the terrace escarpments are fairly steep and resemble fault scarps. In fact it is a fairly common notion that some of these terrace escarpments are faults. It is possible that some minor faults exist in Colorado County and have been covered up by fairly recent deposits but it is considered extremely unlikely that any faults having much throw exist in this region from the fact that none of the older formations of the Gulf Coastal Plain are exposed in the county.

From the trend of the Lissie-Lagarto contact it would appear that there is a very slight upward bulge in the form of a broad anticlinal nose or structural terrace in the region between Columbus, Altair and Rock Island. However, a similar result might be produced by a broad gentle dome-like fold. Again it may easily be due to an old topographic high on the surface of the Lagarto before the Lissie was deposited and the Lissie being thinner there, has since been more or less eroded from this area. If this bulge in the contact is due to an unconformity there may be no up-warping here, at all. It will probably be necessary to drill several deep wells across the center of Colorado County and make a careful study of the beds penetrated before it can be ascertained which of these possible causes has produced this migration of the contact.

Two other pieces of evidence that tend to support the up-warping theory are: (1) The very pronounced downstream extension of the Lagarto along the Colorado River and (2) the slight north or northwest dip (about two feet to the mile) noted in a sandstone-clay contact one-fourth mile below the east bridge at Columbus.

However, it is possible that all these features were produced by an irregular unconformity. It is an established fact that there is a widespread unconformity between the Lagarto and basal Lissie but it is doubtful if this unconformity is very irregular except in the minor details of its surface.

The small patch of limy rocks, probably Lagarto, southwest of Rock Island could also possibly have been produced by a marked local topographic high in the old Upper Lagarto surface but this theory seems more unlikely in the case of this small isolated outcrop of older rocks. This effect could have been produced by the upward growth of a salt dome which raised up the sedimentary beds in this small area thus causing the Lissie beds to be eroded from the surface and the underlying Lagarto to be exposed.

The pronounced double mound found on the prairie eight miles west of Garwood, and which has already been described, strongly suggests a salt dome. However, the uplift here has not been great enough to cause the erosion of the Lissie from the surface. This mound is most easily explained as being produced by a salt dome in its infancy or one in which the core of salt is still very deeply buried. It is possible that some of the other larger peculiar mound-like hills have been produced by small salt domes.

It has been impossible to work out the detailed underground structure conclusively on account of (1) the lack of good exposures or outcrops over much of the county; (2) the irregular bedding and unreliability of the dip in the surface formations all over this region and (3) the scarcity of deep wells and their logs and of samples from these wells.

ECONOMIC GEOLOGY

The only geologic resources of Colorado County which have been developed at all are the underground and surface water, the gravel and silica sand, the timber, and the agricultural resources. Other possible resources are brick clays, molding sands, bentonite, polishing earth, and petroleum and natural gas.

SOIL RESOURCES

Soils well adapted to agriculture, including stockraising, are the most valuable resources of Colorado County and these have been developed to a much greater extent than any of the other natural resources. However, there is still plenty of room for the development of agriculture.

The richest soils of Colorado County are the black land and second river bottom soils. The best soils of the county are therefore found in the western and northwestern portions where the Lagarto clays outcrop, in the southern part of the county in the vicinity of Garwood where the Beaumont clays outcrop, and in a strip of variable width along the Colorado River where the second bottom or Garwood terrace is developed. The first bottom of the river also has excellent soil, but is too much subject to overflow to be certain of a crop. Even the second bottom, north of Altair, is subject to overflow but agricultural products can be grown here with a fair degree of certainty that they will mature.

The soils of the Lagarto Hill Prairie are black clays and loams. The loamy soils occur where sandstones are interbedded with Lagarto clays. In a few areas the sandstones are more prominent than the clays, in which case the soil is sandy or even lacking. Cotton, corn and vegetables are the principal crops grown on the Lagarto Hill Prairie.

The clays of the Beaumont Prairie weather into a black land clay soil which is quite similar to that of the Lagarto except that loamy soil is much less common than it is in the Lagarto Prairie. Products similar to those of the Lagarto are raised on the Beaumont Prairie. The Beaumont Prairie is much flatter than the Lagarto so that rice is very successfully grown in the former region. In fact some of the richest rice farms of the country are found in this area.

The second river bottom soils are mainly a dark loam or clay of considerable fertility. Cotton, grains, pecans, potatoes, and various truck vegetables can be profitably grown on these bottom lands. Wild pecans flourish on this bottom land and it seems likely that the selected cultivated varieties should grow here also. This river bottom territory was originally covered with timber but this has been mostly cut off.

The Lagarto and Beaumont soils have been called Houston clay by the United States Bureau of Soils.

The soils of the Upper Lissie Prairie consist of sandy loams generally of pale buff color which contain much less lime than do the black-land soils. These Upper Lissie soils are called Lufkin sandy loam by the United States Bureau of Soils. They contain an abundance of iron. Strawberries, grapes, raspberries and other small fruits and truck crops have been very successfully grown on this soil in the vicinity of Rock Island, but marketing facilities were poor so that much of the strawberry crop was lost the year this crop was largest. For this reason their raising has been largely discontinued. Since so much of Colorado County consists of this sandy loam more attention should be paid to the raising of small fruits and vegetables here, provided an efficient marketing system, such as a fruit-growers' association, is established. In the extreme southern part of Colorado County in the neighborhood of Provident City a few small, but flourishing satsuma orange groves can be seen. The residents of this section state that once in several years a freeze comes along which kills back the younger shoots of the trees but some of the trees have reached a height of 20 feet in spite of this. It seems likely that the hardier citrus fruits could be grown profitably in this section if their cultivation were gone into on a large scale as is done in Southern California. Smudge pots would be necessary and the trees would have to be fumigated for scale, for the scale have already made their appearance on many of the trees. This would be too expensive unless citrus growing were undertaken extensively.

At present almost all of this Upper Lissie Prairie is devoted to stock raising for which it is very well adapted.

Also in the regions of Eagle Lake and Garwood extensive rice farms are found on this prairie. Rice cannot be grown except where water for irrigation is available.

Much of the irrigation water in southeastern Colorado County is obtained from Eagle Lake, in fact practically none of the water from the lake flows into the Colorado River during most of the year but is diverted for irrigation purposes. Many of the rice farms in the southeastern and southern parts of Colorado County obtain their irrigation water from large shallow wells and if well water is extensively utilized the rice growing district can probably be extended to almost twice its present size.

The poorest soil in Colorado County is that of the Lower Lissie Post Oak Belt. It will not often grow trees that are good for anything but firewood and fence posts and cattle and hogs eke out a scanty existence in this region. Much of the soil is a medium grained buff silicious sand mixed with a certain number of flint or chert pebbles. In some places the pebbles are very abundant and in others scarce. Probably very little can be done with this sand ridge country agriculturally. It is possible that parts of it might grow better trees if the underbrush were kept down and better varieties were planted.

Timber

There are two distinct types of timber in Colorado County: (1) Post oak timber which is principally confined to the Lower Lissie Post Oak Belt and (2) bottom-land timber.

The timber of the Lower Lissie Belt consists predominantly of post oaks with a considerable amount of shrubby undergrowth of yaupon (*Ilex vomitoria*), hawthorn, buckthorn and other shrubs. This undergrowth is especially dense in the neighborhood of streams in the post oak belt.

The post oaks (*Quercus stellata*) in Colorado County are mainly below two feet in diameter and 50 feet in height, although occasionally large trees occur. The average size of these trees is about eight inches in diameter and 30 feet in height. Their main use is for fence posts and fire-wood although the larger trees are probably of value for building material. The post oaks and most other trees are generally draped with Spanish moss.

In the region between Cummins Creek and the Colorado River and more sparsely in other parts of the post oak woods are found a considerable number of small hickories, probably mainly *Hicoria texana.* Live oaks (*Quercus virginiana* and smaller related species) are quite common in much of the post oak belt, especially along the Colorado River bluffs and other streams. However, the live oaks of this belt are generally of a size comparable with the post oaks and not of great value for lumber.

Along lower Piney Creek, three and one-half miles north of Alleyton, is a patch of short leaved pines (*Pinus echinata*) that occupies only a few hundred acres and is surrounded by post oak woods. The pines in this restricted area reach a diameter of three feet and a height of 75 feet and the stand is good except around the borders of the area. The pines here seem to be actually spreading and numerous small pines interspersed with post oaks occur on the border of the area. Many of the large pines are tall and straight and are quite valuable for lumber. Only one large pine and a few associated young trees were seen in Colorado County outside of this patch. This was on the summit of Rocky Hill, three miles southwest of Glidden, where the large tree is known as "the lone pine."

In the southern portion of the area between the Colorado River and Cummins Creek especially on the bluffs are found scattered shrubby cedars, probably *Sabinia virginiana.*

The other timber belt in Colorado County is a strip from a hundred yards to three miles wide bordering the Colorado River and other streams. The broadest belt of bottom timber, as this may be called, is along the Colorado River on the three youngest terraces.

The timber here is entirely hardwood and very varied in character. The largest trees seen were sycamores and live oaks having diameters of four feet. There are also numerous hackberry, ash, elm, black walnut, pecan, and a few wild china trees. Burr oak is occasionally found in the stream bottoms while white oak and other deciduous oaks are frequent locally. Yaupon is very abundant especially in the bottoms of the smaller streams and small palmettoes are occasionally seen. There is a wide variety of other shrubby undergrowth. Long streamers of beautiful Spanish moss hang from many of the trees, especially the live oaks. A considerable amount of this timber is probably of economic value.

WATER SUPPLY

Surface Water.—The only surface water in Colorado County that can be counted upon the year round is found in the Colorado River and in Eagle Lake. This surface water is well adapted to irrigation and the water from Eagle Lake is already being extensively used for that purpose.

Water from Shallow Wells.—Colorado County is abundantly supplied with underground water and practically all over the county fairly good drinking water can be obtained from wells 100 feet or less in depth. There are usually two or more water-bearing strata in these shallow wells and it often happens that if the upper stratum contains bad water good water can be obtained by going a few feet deeper. The usual defect with the well water is the presence of too much lime and occasionally of gypsum.

In the neighborhood of Weimar, on the high ground north of Frelsburg, and on the high bluffs close to the Colorado River, as would be expected, the wells have to be drilled deeper than in other parts of the county. Also in the neighborhood of Weimar, the water, though generally usable, is very hard and not satisfactory for boilers and certain other uses. Also in some of the wells in this region the water is so strongly impregnated with gypsum that it can scarcely be used for drinking or any other purpose. In a well northeast of Weimar, located on the southwest bluff of the Colorado River a few miles below the Fayette County line, the water struck at about 100 feet, is slightly brackish. This well, like the city wells at Weimar, probably obtains its water from the Lapara member of the Lagarto. The Lapara seems to contain more of the undesirable water soluble salts than does the rest of the Lagarto.

Most of the shallow wells north and west of a line extending from New Ulm south to the mouth of Skull Creek and west and northwest to Rock Island and Sheridan, obtain their water from the sandstone and sand beds in the Lagarto. The wells south and east of this line and also some of those located on the second and third and even higher terraces of the Colorado River get their water from the Lissie sands and gravels or the equivalent river terraces. The water from the Lissie is generally lower in lime than that from the Lagarto but that from the uppermost part of the Lissie often contains an appreciable amount of lime, while that from the Lower Lissie is nearly lacking in it. Water from the Lower Lissie is generally the softest water in the county, although some excellent water is obtained from the Lagarto.

Some of the wells, especially those located on land less than 175 feet above sea level, in the neighborhood of Eagle Lake and Garwood produce large quantities of excellent water from depths of 200 feet and less. Water from such wells is often used to irrigate good sized rice farms and could be used to advantage, even where in smaller volume, to irrigate fruit farms and truck gardens.

Flowing Artesian Wells.—Besides the shallow wells from which the water has to be pumped, there are three flowing artesian wells in Colorado County and one a short distance across the line in Lavaca County. These wells are located on the geologic map. They are: (1) The Columbus well located just west of the Columbus east bridge; (2) the O. K. Oil and Gas Company well located three miles southwest of Eagle Lake City; (3) the Cheetham well located one-half mile northeast of Cheetham, and (4) the Laas Number 1, of the Lavaca County Oil Company, located three and one-half miles south of Oakland. An artesian flow was also reported from the Columbus-Bernardo well which is drilling three miles north of Ramsey, but was cased off.

The Laas well has a much larger flow than any of the others although this may be due to the fact that the other wells have all been drilled several years ago. A very rough estimate on the flow of the Laas well gives 500 gallons per hour and all this comes from around the casing. The head on this water is quite strong but the height to which the water will rise has not been measured. From the amount of pressure it exerts at 250 feet above sea level it seems probable that the water will rise to 300 feet above sea level. The water from the Laas well is excellent. It comes from two strata, 405 and 812 feet below the surface respectively, but its head is derived from the 812-foot level. Water sands were also struck in this well at 1070 feet and 1415 feet, but most of the water comes from the higher sands.

The water horizons in the other wells are not so definitely known. One of the drillers of the Cheetham well reports a fairly good flow of good artesian water at 600 feet. This well was drilled many years ago and the casing has since rusted out at the surface but a stream of brackish water containing considerable gas, is still flowing from the four and three-fourth-inch casing at the rate of about 259 gallons per hour. The gas and salt water is said to come from below 1000 feet and this has contaminated the artesian flow of fresh water from 600 feet. Probably a good part of the water has been cased off.

The Columbus well is said to be about 1400 feet deep and was drilled many years ago. At present a stream of good fresh water is flowing from a one-inch pipe at the rate of about 25 gallons per hour. The flow was reported to have been somewhat larger originally. There is a small amount of gas coming from this well also.

The Eagle Lake well is 1506 feet deep and the log does not indicate where the artesian flow was struck. In fact the drillers were apparently unable to tell this and numerous sand and sandstone beds were passed through all the way down. It is probable, however, that the water comes from below 1000 feet. Warm sulphur water, containing bubbles of gas, flows from the well in a stream yielding possibly 100 gallons per hour or more.

An artesian flow of good water was struck at 239 feet in the Columbus-Bernardo well, but this was cased off. Other water strata were also struck lower in the well according to reports.

Artesian Reservoirs.—The principal artesian reservoir in Colorado County is apparently the Lagarto sandstones and sands for the biggest artesian flows have been struck in that formation.

The Oakville sandstone ought to constitute an important artesian reservoir in parts of this county and some of the flowing wells probably obtain their water from this sandstone.

The Catahoula sandstone underlying Colorado County may furnish a suitable artesian reservoir, but the sandstone apparently lenses out in this region so it is not considered as favorable as some of the higher sandstones and sands.

Area of Flowing Wells.—On account of the small number of deep wells drilled in Colorado County the area of flowing wells cannot be accurately defined. Also, on account of the lenticularity and irregular distribution of the sandstone beds in the Lagarto and Oakville it is probable that certain local areas are not underlain by a suitable sand reservoir. The portion of Colorado County having an elevation of less than 275 feet above the level of the sea is considered favorable for flowing artesian wells. In general in the portion of the county lying south and east of a line extending from Frelsburg south-southeast to Sheridan flowing wells should be obtained. They can probably also be obtained much farther north and west in the bottoms of Cummins Creek, Colorado River, the Sandies creeks and Navidad River. It is likely that such wells can be had on the fourth terrace of the Colorado River and on all terraces below this in Colorado County, thus extending the area of flowing wells beyond the Fayette County line along the river.

GRAVEL

Extensive deposits of both road and concrete gravel are located in Colorado County. These deposits are all of Lissie age. In the past gravel has been removed from about ten good sized pits but while the writer was in the county only four of the pits were operating. In spite of the removal of large quantities of the best gravel in the areas most accessible to transportation the total gravel resources of Colorado County have scarcely been touched and many very extensive deposits have never been worked at all. It is true that the greater part of the total gravels are not of the best quality on account of part of the pebbles being too large but many millions of cubic yards of high grade gravel are still available. It is also possible to screen out the large pebbles when they are not too abundant. Unfortunately many of these deposits are situated at distances too remote from the railroads to be profitably worked at present, but these can be developed after the more accessible deposits have been depleted. All the gravels in Colorado County are

TABLE 5

RESULTS OF TESTS MADE ON COLORADO COUNTY GRAVELS AND SILICA SANDS

Location of Sample	SCREEN-SIEVE ANALYSIS: Retained on 2″ screen	Retained on 1½″ screen	Retained on 1¼″ screen	Retained on 1″ screen	Retained on ¾″ screen	Retained on ½″ screen	Retained on ¼″ screen	Retained on 10 mesh sieve	Retained on 20 mesh sieve	Retained on 30 mesh sieve	Retained on 40 mesh sieve	Retained on 50 mesh sieve	Retained on 60 mesh sieve	Retained on 80 mesh sieve	Retained on 100 mesh sieve	Retained on 200 mesh sieve	Passing 200 mesh sieve: By analysis	Passing 200 mesh sieve: By washing	Cementation Test: Material as received (C)	Cementation Test: Material under ¼ in. as received (B)	Weight of Sample (in pounds)	REMARKS
Alleyton Pit	5.0	26.7	9.1	7.7	4.1	5.2	24.9	18.8	2.6	0.5	....	0.2	....	0.1	....	0.05	0.05	....	Not given	Not given	10	Good road gravel.
Altair, 1½ mi. N. E.	8.5	5.3	5.7	2.2	4.2	4.1	14.4	21.5	14.6	9.0	5.3	5.1	2.0	1.3	0.5	0.5	0.4	3.8	Not given	64—Poor—Did not slake	41	Good concrete aggregate if washed and screened.
Altair Pit, No. 1	0.0	8.9	1.5	7.5	9.4	7.9	16.1	24.2	11.1	3.1	0.8	0.9	0.6	0.4	0.2	0.7	0.5	6.1	65—Poor—Did not slake	Not given	64	Good concrete aggregate if washed and screened.
Altair Pit, No. 2	0.0	9.6	6.9	6.8	3.4	5.8	12.9	22.4	10.1	3.1	0.3	2.9	1.0	0.5	0.3	0.5	0.3	13.2	198—Fair—Slaked a little	Not given	Not given.	Good for road surfacing.
Columbus (Horton & Horton)	....	....	....	....	....	....	....	2.8	7.4	20.8	24.8	35.5	5.9	2.8	0.6	0.3	0.1	....	....	....	Not given.	Too poorly graded for strong mortar.
Columbus (Horton & Horton)	....	....	....	....	....	....	0.3	22.1	27.3	27.0	8.7	6.3	3.0	1.8	0.8	1.4	1.3	....	....	....	75	Good mortar sand.
Columbus (Horton & Horton)	....	....	....	....	....	10.0	68.0	9.2	0.9	0.5	0.2	0.3	0.3	0.1	0.1	0.2	0.2	....	....	....	11	Good screened and washed gravel.
Columbus (Horton & Horton)	....	....	3.2	28.2	25.5	26.0	15.2	1.7	Passing 10 mesh sieve=1.2%.												12	Good concrete aggregate.
Columbus (Gilmer & Tanner)	2.7	8.6	3.5	5.0	4.9	9.7	20.6	18.1	8.5	6.7	2.5	0.9	2.0	0.6	0.5	0.5	0.5	6.9	98—Fair—Did not slake	....	56	Good road gravel.
Columbus (Gilmer & Tanner)	18.5	12.0	8.5	6.7	7.5	8.7	11.4	11.3	8.4	13.6	4.9	2.1	0.6	0.3	0.3	0.4	0.5	2.8	....	....	65	Good concrete gravel when washed and large pebbles removed.
Columbus Pit	13.3	5.3	3.0	7.1	6.5	8.3	18.1	18.4	10.7	8.4	2.6	2.3	0.7	0.6	0.2	0.5	0.2	7.0	....	159—Fair—Slaked in 10 min.	23	Good road gravel if large pebbles are removed.
Ellinger, Pit No. 2	2.0	34.0	....	7.4	8.5	5.9	4.4	6.6	4.5	3.1	2.6	2.5	2.1	2.4	0.2	0.2	2.7	12.9	208—Fair—Slaked in 45 min.	....	7.5	Good road gravel.
Ellinger, Pit No. 1	2.0	13.4	8.5	5.6	8.9	9.6	11.4	19.7	6.3	1.3	0.4	0.8	0.6	1.2	0.3	0.3	1.3	10.4	....	54—Poor—Did not slake	17.5	Good concrete gravel.
Glidden (Haden & Austin)	19.0	9.4	11.0	12.2	8.8	8.2	8.8	8.1	8.4	6.0	1.5	1.2	0.8	0.9	0.7	0.9	0.3	12.8	58—Poor—Slaked some	125—Fair—Did not slake	79.0	Good road gravel if large pebbles removed.
Glidden (Oaks land)	....	....	....	2.4	5.9	13.3	26.4	17.1	9.0	3.3	3.4	1.6	0.8	0.4	0.7	1.3	1.8	12.6	76—Poor—Did not slake	....	Not given.	Good wearing surface for gravel roads.
Glidden (Ilse Pit)	20.2	22.9	2.8	10.5	19.1	15.0	13.4	7.7	1.5	0.6	0.5	0.5	0.1	0.5	0.1	0.6	0.2	4.0	62—Poor—Did not slake	....	77	Good base for roads.
Glidden, 3½ mi. N. W.	....	6.3	....	2.2	1.4	4.3	6.8	28.2	17.9	7.5	3.0	2.4	1.0	0.9	0.3	1.4	1.5	11.9	....	67—Poor—Did not slake	17.5	Not good, unless a binder is added.
Glidden, 1½ mi. S. W.	14.5	10.2	0.6	8.6	3.1	6.2	14.8	9.5	8.6	11.4	4.3	4.2	1.6	1.3	0.6	1.0	0.5	13.5	Did not slake	205—Fair—	41.5	Fair road gravel if large pebbles removed.
Glidden, 1½ mi. S. W.	6.2	18.6	7.3	13.2	6.9	8.9	12.3	14.2	10.8	1.2	0.3	0.8	0.5	0.6	0.4	0.7	0.7	2.6	....	10—Very poor—Did not slake	43	Satisfactory concrete aggregate.

Tests and analyses made by G. A. Parkinson, Engineering Division of Bureau of Economic Geology and Technology.
NOTE: Figures given in per cent; material on 2 inch screen was eliminated before making analysis.

entirely silicious, most of the pebbles being composed of chert and quartz, though pegmatite is common.

Road Gravels.—The term road gravel as ordinarily used designates a gravel, composed of hard tough pebbles largely, that contains enough sand to fill in the spaces between the pebbles and enough clay to bind the pebbles and sand grains together sufficiently well to make a good road surface. A true road gravel can be used for surfacing roads without having to be mixed with other material. The pebbles in a good road gravel should range between two inches and one-fourth of an inch in diameter. It is impossible to state the

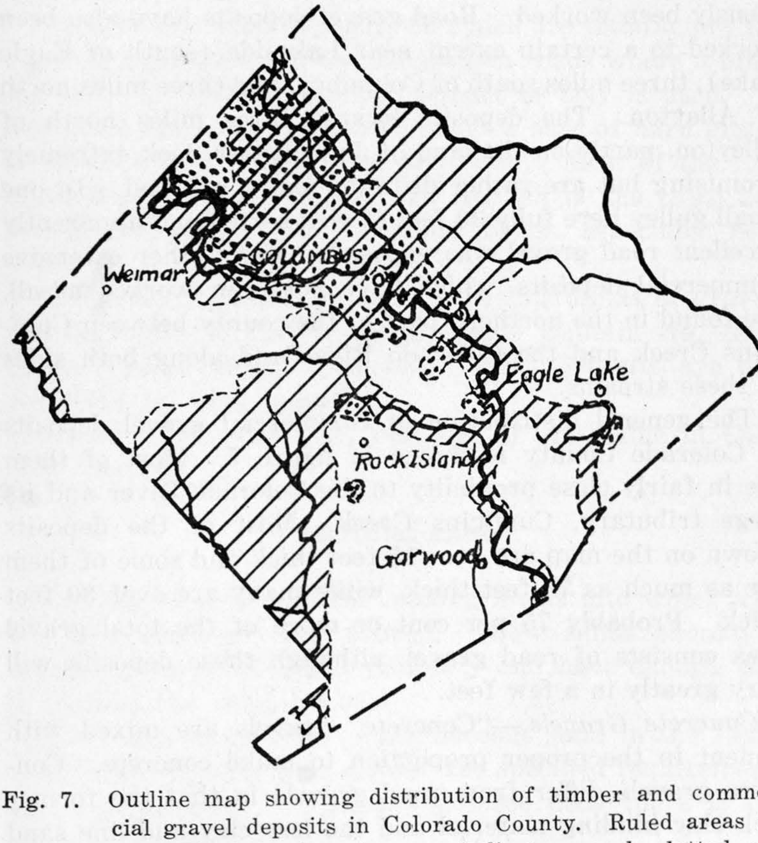

Fig. 7. Outline map showing distribution of timber and commercial gravel deposits in Colorado County. Ruled areas indicate timber; dotted areas indicate gravel; dotted and ruled areas indicate both gravel and timber.

exact proportion of clay, sand and gravel that is necessary to make a good road gravel for this is variable in different deposits. It is thus necessary to make practical tests on representative samples from each deposit. This work has been done by the Engineering Division of the Bureau of Economic Geology and Technology on the Colorado County gravels and silica sands and the analyses are given in Table 5. The use of each sample tested is found under "Remarks" in this table.

Several other deposits of commercial gravel have been seen by the author and one of these that still probably contains much commercial gravel (the Lorine pit) has previously been worked. Road gravel deposits have also been worked to a certain extent near Lakeside (south of Eagle Lake), three miles south of Columbus, and three miles north of Alleyton. The deposits located three miles north of Alleyton, partly on the land of John Ritter, look extremely promising but are rather distant from a railroad. In one small gulley here fully 30 feet of well sorted and apparently excellent road gravel was exposed. Many other extensive commercial deposits, which have not been worked at all, are found in the northern part of the county between Cummins Creek and the Colorado River and along both sides of these streams.

The general distribution of commercial gravel deposits in Colorado County is shown in figure 7. Most of them are in fairly close proximity to the Colorado River and its large tributary, Cummins Creek. Most of the deposits shown on the map are over 15 feet thick and some of them are as much as 75 feet thick, while many are over 30 feet thick. Probably 75 per cent or more of the total gravel area consists of road gravel, although these deposits will vary greatly in a few feet.

Concrete Gravels.—"Concrete" gravels are mixed with cement in the proper proportion to make concrete. Concrete gravels differ from road gravels in that the former lack clay binding material and the less clay and fine sand that they contain the better the gravel is for concrete aggregate.

If less than five per cent of clay and silt is present these impurities can usually be washed out with ease and in some gravel as much as 10 per cent of the material that will pass through the 200-mesh sieve (200-meshes to the linear inch) can be so readily removed by washing that the gravel can be profitably marketed for concrete aggregate. It is often possible to use a limited percentage of pebbles over two inches in diameter in concrete gravels although these large pebbles are very unsatisfactory in road gravels. More sand can also be present in concrete gravels than in most road gravels. Good concrete gravels should not have coatings of clay on the pebbles.

It should be stated that gravels which are satisfactory for concrete aggregate can also be used on roads where a binding material such as asphalt, cement or clay is used. In fact good asphalt roads have to have a base of hard gravel or crushed rock in order to wear well. Most of the concrete gravels in the county are located on the third and fourth bottoms of the Colorado River, especially near Columbus.

The principal qualifications for various kinds of gravels can be found in University of Texas Bulletin No. 1839, pages 6-12.[1] Several Colorado County deposits are also described in this bulletin.

Gravel is the only road material of any value in Colorado County.

MOLDING SAND

Molding sand is used for making molds into which molten iron and steel are poured. These sands should be angular-grained; of slight fusibility and have enough clay to cement the sand grains.

There are many beds of argillaceous sand in the Lissie of Colorado County that answer the specified requirements for molding sand. In many of these beds there is not

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[1]Nash, J. P., et al., Road-building Materials in Texas, Univ. of Texas Bull., No. 1839, pp. 6-12 and 39-42, 1918.

enough clay present but clay beds are close at hand and could easily be mixed with the sand in the proper proportion. Samples of Lissie sand from three miles east of Alleyton, from Garwood and from two miles southwest of Columbus were submitted to Mr. A. D. Potter, of the Division of Industrial Chemistry, Bureau of Economic Geology and Technology, for testing. He reports that they are a good grade of sharp sand and might be used in core work, but have not sufficient binder for regular molding sand. The bed of white, splotched with red and yellow, soft argillaceous sandstone found on the Sealy road, three miles east of Alleyton, a few miles west and northwest of Rock Island, and other localities in the county often has a thickness of ten feet and covers many acres at or near the surface. Non-calcareous clay beds are associated with it and a small amount of this clay can be added where necessary to make a suitable molding sand. It appears that these argillaceous sandstone or sand beds might be profitably worked for molding sand but more extensive prospecting as well as more tests should be made on them before opening any molding sand pits. Several beds of ferruginous, argillaceous sand and fine gravel exposed between Columbus and Eagle Lake might also be profitably worked.

SILICA SAND

Good silica sands which are of value for mixing with lime to make mortar or with cement to make smooth concrete are found in the Lissie gravels. However, it is very rarely that any extensive deposit of pure silica sand is found and silica sand is best produced in connection with gravel pit operations. Samples of silica sands from the Lissie have been tested and the tests are shown in Table 5.

The coarser grained, friable Lagarto limy sandstone and sand such as that found in the vicinity of Borden is composed mainly of silicious grains with more or less limy cement and ought to make a satisfactory mortar or concrete sand when the consolidated portions are crushed.

Some of this sandstone is fairly well sorted as shown by the mechanical analyses in Table 2.

BUILDING STONES

No rocks occur in Colorado County which are suitable for building stones although some of the harder calcareous sandstone will make satisfactory well curbing and stone walls. On account of its irregular bedding the sandstone will rarely break out into even blocks.

CLAYS

There are enormous deposits of clay in Colorado County, especially in the Lagarto formation. However, large deposits of fairly pure clay are found in the Upper Lissie, and the Beaumont.

Clays of the Lagarto.—The clays of the Lagarto are buff and pale gray in color and all are fairly calcareous. The greater part of these clays contain abundant calcareous concretions from one-fourth inch to two inches in diameter. These concretions at once condemn any clay as a commercial possibility where they are of any size or at all numerous. However, many extensive and thick beds of Lagarto clay can be found in which the calcareous concretions are very small and not very numerous. A sample of this latter clay (C 1982) from three miles southeast of Alleyton was submitted to the Division of Industrial Chemistry of this Bureau and tested by Mr. A. D. Potter, who reports as follows:

> "The stiff mud test pieces of sample C 1982 showed a rather high linear drying shrinkage, 12.90 per cent, but did not crack on drying. It showed medium to fair plasticity when made up with 21.90 per cent water. This set was fired through the entire temperature range and gave a uniform cream color with moderate hardness. All test pieces. however, showed a slight tendency to crack and warp. This tendency would condemn the sample as a commercial possibility. The dry press series of this sample cracked badly on firing and the entire set was drawn from the furnace at 950° C."

Clays of the Lissie.—In certain parts of Colorado County thick and fairly extensive beds of slightly sandy clay are found. These are usually mainly of a buff color more or less mottled with red and gray. A good bed of this clay (C 1983) is found along the Columbus-Altair road four miles north of Altair. Mr. Potter reports on a sample of this clay as follows:

"The stiff mud test pieces of sample C 1983 showed a linear drying shrinkage of 10.25 per cent and medium to fair plasticity when made up with 20 per cent water. The series was burned through the entire temperature range and gave a fair red color with moderate hardness. The test pieces showed a slight tendency to crack and all warped badly. The dry press test pieces of this sample were burned through the entire temperature range and gave a light red color graduating to a darker shade at the higher temperatures. The test pieces drawn at the first three intervals, 950°, 990° and 1030° C were very soft. After this range they became somewhat harder but a hardness sufficient to withstand ordinary usage without excessive loss was not obtained until a temperature of about 1200° C was reached. Since this clay could not be used for anything except the manufacture of ordinary common brick this high temperature is prohibitive. Furthermore all test pieces of this series had several small cracks."

A sample of the white bentonite, stained with red along joints (C 1981), from three miles northwest of Rock Island was also tested for a brick clay with the following results:

"The stiff mud test pieces of sample C 1981 showed a high linear drying shrinkage, 18.5 per cent, and cracked badly on drying. The sample showed good plasticity when made up with 31.3 per cent water. This set was not fired. The dry press test pieces of this sample were considerably cracked and showed a tendency to fuse at 950° C. The entire set was drawn from the furnace at this temperature."

It is thus apparent that the Colorado County clays are not suitable for making high grade brick or other uses, although some of them may make fair brick if the tendency to crack can be overcome. The samples tested were the most promising looking clays seen that were within easy access to railroads.

FULLERS EARTH

No high grade fullers earth was noted in Colorado County, although some of the Lagarto clay makes a rather low grade fullers earth.

BENTONITE

The bed of bentonitic clay found in the Lissie has been described under "Petrography of the Lissie." This bed is located about three miles northwest of Rock Island, being exposed in the banks of East Sandies Creek. It is almost pure white with numerous streaks and splotches of red. These red areas owe their color to iron oxide which has filtered down from the overlying gravelly sand and clay. It is exposed in the banks of Sandies Creek for over a mile. The base was not seen but there is fully 10 feet of the bentonite exposed so that this must be a very large deposit. This material differs from other clays in that it slakes quickly and the particles during the slaking process are often thrown off with force. The dried material will absorb considerably more water than ordinary clay for it is apparently composed almost entirely of the mineral leverrierite which has the property of readily absorbing a great deal of water which causes it to slake rapidly. The material is thought to be an altered fine volcanic ash, but no glass grains were observed in the samples of this Colorado County bentonite that were examined, although a small number of sand grains, apparently mostly of normal sedimentary origin, are found in it.

An analysis made of this material by J. E. Stullken, of the Industrial Chemistry Division of this Bureau is as follows:

Silica	63.40
Alumina	19.54
Ferric Oxide	4.26
Lime	0.31
Magnesia	None
Potassium Oxide	0.74
Sodium Oxide	2.66

Loss on Ignition (H_2O)	9.12
Total	100.03

The analysis is very similar to samples of bentonite from the Laramie Basin, Wyoming, which are quoted by Nelson[1] for comparison with the bentonites of Tennessee, etc.

The alumina, lime, and magnesia content is slightly lower than most of the bentonite analyses but one sample of bentonite analyzed has a smaller percentage of alumina than does this sample. The absence of magnesia in this sample is the most noteworthy difference from other bentonite analysis.

On account of the rather high red ferric oxide content in the Colorado County bentonite the bentonite seen on the outcrop cannot be used in the manufacture of high grade smooth paper, which is the principal use of bentonite, unless the iron is removed chemically. It is quite possible, however, that a short distance back from the outcrop where the deposit is covered by a few feet of over-burden the iron may not be so abundant and may possibly be almost absent. If much of this material free from iron stain is found the deposit should be of considerable value for it is only about one and one-half miles from the S. A. & A. P. Railroad. This deposit can be prospected with a large soil auger.

POLISHING EARTH

Beds of very fine grained soft calcareous sandstone or silt are found in the Lagarto formation. When ground up this makes an excellent scouring and polishing earth. A deposit of this material a few miles across the Colorado County line in Fayette County has been worked by the Saxo Products Company of Houston and was sold under the name of Saxa. This earth was said to have medicinal value and was claimed to be beneficial in cases of cancer, old sores, piles, fresh cuts, sore feet, burns, ring worm, indigestion, dyspepsia, kidney trouble, torpid liver and as a dentifrice. An analysis made of this material shows it to be composed of

[1]Nelson, W. A., Volcanic Ash Bed in the Ordovician of Tennessee, Kentucky, and Alabama, Bull. Geol. Soc. Am., V. 33, p. 614.

silica, lime, alumina, ferric oxide, potassium oxide, and sodium oxide. It resembles rather closely an analysis of typical Lagarto sandstone. No evidence of any medicinal material is shown by the analysis and if such substances are present they evidently occur only in traces.

As a fairly coarse polishing earth this material, when ground up, is very good but is too coarse grained and will scratch too much to give the highest type of polish. It should never be used for a dentifrice.

OIL AND GAS POSSIBILITIES

Up to the present time there has been no commercial oil or gas production in Colorado County. However, only seven wells over 900 feet in depth have been drilled in Colorado County and three a few miles across the county lines in Austin, Wharton and Lavaca counties. The wells are all indicated on the geologic map. Of these ten wells only the Texas Company's Schaffner No. 1, the Lavaca County Oil Company's Laas No. 1, the Columbus-Bernardo Company's Kiser No. 1, and the Cheetham well have been drilled down over 2000 feet. The other wells range in depth from 923 feet to slightly over 1500 feet.

Oil and Gas Shows or Seeps.—Gas has been struck in small quantities in the majority of the wells over 900 feet in depth and oil and gas shows have been reported in practically all these wells. Gas is still bubbling in quantities large enough to be lighted with a match from the Cheetham well, the Columbus Artesian well, the O. K. Oil and Gas Company's Eagle Lake well and the Glidden Roundhouse well. It is probable that most, if not all, the gas in the Glidden and possibly the Eagle Lake well is hydrogen sulphide, but odorless natural gas in considerable quantities is coming from the Cheetham well. A fair sized stream of natural gas was struck in a shallow well near Ellinger several years ago and an analysis is said to show that this gas contained 4.2 per cent ethane. A good sized oil show, with possibilities for commercial production, is reported to have been struck in the Ellinger-Gonzales Oil Company's well near Ellinger between 700 and 800 feet.

Definite oil shows were noted by the writer in three shallow water wells in the county, namely: (1) Three miles south of Rock Island in a well on the place of H. W. Patrick; (2) two and one-half miles northeast of Frelsburg on the land of Antonheinsohn Brothers and Louis Pflughaupt, on top of a gentle mound-like hill; and (3) eight miles southwest of Garwood on land belonging to Rollington, on top of the prominent double mound previously described. Oil seeps are reported to be very abundant on the surface in the Rock Island vicinity in times of long continued wet spells. Many springs and water seeps as well as stagnant pools which are coated with a thin skim of ferruginous material, possibly iron hydroxide, are often mistaken for oil seeps by the uninitiated. Such skims are common all over the county.

Possible Oil Producing Formations.—Under conditions of normal anticlinal folding, if such conditions exist in Colorado County, probably the most promising formations for oil production here are the Eocene, Yegua and Cook Mountain formations. These are the formations that apparently produce the oil in the Webb and Zapata county fields. The top of the Yegua should be between 2500 and 4000 feet below the surface in Colorado County. It is at shallower depths in the northwestern part of the county and deeper in the southeastern part on account of the regional southeast dip. The top of the Cook Mountain, which underlies the Yegua, will probably be encountered at depths of 3200 to 4700 feet. We thus see that oil in commercial quantities will probably not be struck in Colorado County under possible conditions of ordinary gentle folding unless deep test wells are put down.

Other formations which may possibly produce oil and gas at shallower depths, especially under salt dome conditions, are the Lagarto, Oakville and Fayette. Most of the gas which has been struck in the Colorado County wells apparently comes from the upper part of the Oakville. The Lagarto and Oakville or their equivalent, the Fleming, are apparently the horizons from which most of the oil in the Gulf Coast salt dome fields comes. However, near the coast these formations were apparently laid down largely under marine conditions and they are for this reason better adapted to oil formation and accumulation. On account of their predominantly continental origin in Colorado County and the fact that they are underlain by a considerable thickness of non-marine Oligocene clays it is not so likely that oil in large quantities will be found in the Oakville-Lagarto here. The irregular lenticular bedding of these Miocene-Pliocene deposits would be apt to prevent the oil from migrating up the dip all the way from the coast region where they are known to be oil-bearing. It is conceivable that this may have occurred locally to a certain extent. It is also possible to have oil accumulation in these formations in Colorado County without any definite structure, provided there are persistent sand beds which lense out in this region but such oil pools would be apt to be rather small and rather narrow. However, the Oakville and Lagarto may be quite productive if the underlying formations have been broken up by salt dome formation.

The Fayette sandstone, the top of which probably lies about 500 feet above the top of the Yegua, is a possible oil and gas reservoir but at the present time only a few shallow wells in Starr, Live Oak, Zapata and Webb counties apparently get their oil or gas out of the Fayette.

Oil and Gas Structures.—Colorado County is situated near the inner margin of the salt dome region of the central Gulf Coastal Plain. For this reason salt dome production seems to be the most promising possibility for petroleum and natural gas production.

Salt Domes.—Salt domes in the Gulf Coastal Plain usually can be identified by the occurrence on the almost perfectly level surface of the plain of rounded or oval-shaped more or less elevated areas. These large mound-like elevations vary from a few feet to eighty feet in height above the surrounding country and have a maximum diameter of one-eighth mile to several miles. These elevations are produced by the growth, beneath the surface of masses of crystalline rock salt, anhydrite, gypsum, dolomite, and sulphur or some of these substances. A fairly extensive literature has been built up around the occurrence and origin of the salt domes so the writer will not go into details about them here. It suffices to state that these plug-like masses, usually composed mainly of common salt, halite, have pushed through some of the deeper sedimentary strata and have arched up those nearer the surface. In some cases the plugs have even reached the surface and the salt being dissolved, a lake or depression has been formed where the elevation formerly existed. In some of these salt domes oil has been trapped around the sides of the salt core.

In the southern part of Colorado County a few mound-like elevations, an acre or more in area and rising as much as 20 feet above the surrounding level prairie, are found. These have already been described under "Topography" and are shown on the geologic map. Some of these mound-like elevations, especially where capped with gravel, are probably due to differential erosion. There is one large mound in particular that is possibly a salt dome. This is the large double mound eight miles southwest of Garwood, I. and G. N. Railway Company Survey, Section 45. There is also a small oil seep in a well located on top of this mound, which has already been noted. However, the Upper Lissie apparently covers the surface of this mound as well as the surrounding prairie so if this is a salt dome the salt core must be deeply buried and the doming probably has taken place in comparatively recent time. It is possible that some of the other large mounds found in southern Colorado County are of this same type.

What is considered to be possibly a salt dome also, although it is doubtful from topographic evidence, is found four miles southwest of Rock Island on Sandies Creek. Here there is an area of limestone and limy sandstone and clay, unlike anything seen in the Lissie. These limy rocks are thought to be of Upper Lagarto age. They are surrounded on all sides by extensive areas in which the younger Lissie outcrops. These facts, as has been previously stated, suggest an uplift and the restricted area in which the older rocks are found suggests that a salt plug was the agency which produced the uplift. The alternate hypothesis of an old topographic high in the erosion surface at the top of the Lagarto has already been discussed.

It should be called to mind here that not all the known salt domes have proved to contain petroleum in commercial quantities, but the chances of striking it on salt domes are vastly better than where there is no structure.

In the rolling country forming the Lower Lissie Post Oak Belt and the Lagarto Hill Prairie the existence of salt domes can be determined only with the greatest difficulty, if at all, because it is usually impossible to distinguish hills produced by erosion from salt dome hills and practically no reliable dips can be found in this area.

There are four areas in northwestern Colorado County in which the surface soil is so saline that vegetation will not grow, but it is possible in all of these cases that the salt may be derived from the Lagarto clay which outcrops in all four areas. Three of the areas are small elongated depressions or draws, in fact one of these salty areas located three miles southeast of Ellinger on the land of A. Kreitz occurs in the bed of a small creek. The other two salt depressions or sloughs have no definite stream channel in them, but both finally drain into the Colorado River. These were described under "Topography" (Lagarto Hill Prairie). One is located on land belonging to Frank Walzel near the Fayette-Colorado County line about four miles northeast of Weimar. Here the salt forms a crust in the middle of cultivated fields. The ground is distinctly marshy for some time after a heavy rain and small ponds are found in places. The other so-called salt slough is found one mile south and southeast of Borden on the land of Ed. Barton and H. C. Greak. This is somewhat similar to the one previously described except that it is not so poorly drained nor so well marked and there is less salt at the surface. Both of these salty depressions strike about N. 80° W. The fourth salty area is found three and one-half miles southwest of Borden on the land of W. A. Rogers. In this case the land is salty and in several places a crust of salt is found that almost completely encircles the small hill on which Mr. Rogers' house is located. Rogers states that the salt areas have been increasing in size in recent years.

In is quite possible that the salt comes from the underlying Lagarto clays in all these places mentioned by normal capillary action, but it is also possible that the salt may have been concentrated owing to the occurrence of small faults along which saline waters may rise. They do not resemble sunken salt domes in shape at all. The writer would not advise anyone to drill for oil in these salty areas unless more evidence bearing on the origin of the salt is found.

A dome-shaped hill, about five acres in extent, is found two and one-half miles northeast of Frelsburg on the land on Antonheinsohn Brothers and Louis Pflughaupt. Limy clays, which apparently belong to the Lagarto, outcrop over most of this hill and the hill is almost surrounded at the base by the red gravelly sands and clays of the Lissie as shown on the geologic map. This hill is also somewhat higher than the immediate surrounding territory. A small oil seep was noted in the well near the summit of the hill. It is possible that this hill may be a salt dome but this is very doubtful on account of the nature of the topography and the close proximity of the normal Lissie-Lagarto contact.

Structural Terrace?—There is another poorly defined area in Colorado County in which there is a possibility that oil or gas or both may occur in paying quantities. This is the area where the Lagarto contact makes such a pronounced downstream extension, namely between Columbus and Altair. Lagarto rocks are also found within fifty feet of the surface or less over much of the area between Altair and Rock Island as shown by the logs of shallow wells. In fact a gray manganiferous clay which resembles Lagarto, outcrops in the bed of Crasco Creek for some distance above and below the bridge over Crasco Creek east of Rock Island. The possibilities of this being a structural uplift, and hence a possible trap for petroleum and natural gas, have been discussed under "Structural Geology." If this is an uplift and there is enough reversal of dip it ought to be the largest reservoir for petroleum in the county.

Summary of Oil and Gas Possibilities.—It should be borne in mind that the minor structural features of Colorado County and hence the possibilities for commercial oil and gas production cannot be worked out satisfactorily owing to the nature of the formations together with the lack of good exposures. The presence of gas in so many of the deeper wells is an encouraging sign but does not warrant the conclusion that commercial quantities of either gas or oil exist. It is also true that very few, if any, of the wells in the county have been deep enough to test out the most promising formation. The writer believes that the most favorable areas to test are those he has mentioned in the last few paragraphs. The areas where salt is found at the surface do not appear so hopeful as the other areas mentioned above. Colorado County is situated 30 or 40 miles from the nearest commercial production at present which makes any drilling here a distinct "wild cat" operation, but the writer would certainly not condemn the county as a future source of these valuable products.

OTHER POSSIBLE RESOURCES

No sands in Colorado County were seen which would be of value in glass making on account of their iron content.

There are impure, caliche-like limestones of local distribution in the Upper Lagarto between Columbus and Altair and south of Rock Island but they are not considered of value in lime manufacture and are rather inaccessible to transportation.

WELL RECORDS

The logs of all the deeper wells in Colorado County that were available are given below.

Log of the Ellinger-Gonzales Oil Company's Well No. 1. Located three miles east of Ellinger, Colorado County, Texas.

	Depth in Feet From	To	Thick-ness
Lower Lissie Terrace:			
Sand and gravel	0	10	10
Lagarto:			
Sand rock	10	25	15
Clay	25	35	10
Sand rock	35	47	12
Sand and boulders	47	61	14
Yellow clay	61	73	12
Sand rock	73	84	11
Hard gumbo	84	110	26
Soft gumbo	110	120	10
Hard gumbo	120	135	15
Hard sand rock	135	139	4
Lapara:			
Blue gumbo, few boulders	139	160	21
Pyrite of iron	160	161	1
Gravel sand and clay	161	165	4
Soft shale and gumbo	165	186	21
Gravel and boulders	186	206	20
Sand and shale	206	228	22
Gumbo, showing gas	228	249	21
Gumbo and shale	249	269	20
Shale and boulders, (288 feet) gas showing	269	328	59
Water sand	328	348	20
Gumbo	348	429	81
Rock	429	473	44
Hard gumbo and lime	473	488	15

Log of the Lavaca County Oil Company's well, Laas No. 1 Located four miles north of Sublime, Lavaca County, Texas, Jack Survey, south side.

	Depth in Feet From	To
Lagarto:		
Soil and clay	0	15
Rock	15	20
Gumbo and boulders	20	40
Sand, gas showing	40	60
Gumbo	60	70
Sand rock	70	102
Gumbo	102	124
Rock	124	130
Gumbo	130	140
Sand rock	140	170

Gumbo	170	210
Sand	210	222
Gumbo	222	242
Sand rock	242	265
Gumbo	265	281
Sand rock	281	305
Gumbo	305	326
Sandy shale	326	357
Gumbo and boulders	357	380
Sand and gravel, hard	380	405
Sand and gravel, artesian water, fresh	405	508
Gumbo	508	530
Sand	530	540
Sand and shale, showing gas and oil	540	564
Gumbo	564	578
Sand and shale, showing gas	578	634
Gumbo	634	798
Sand and shale, showing gas	798	802
Gumbo	802	812
Sand, showing gas, flowing artesian fresh water	812	818
Gumbo	818	835
Sandy shale	835	855
Gumbo	855	861
Shale	861	890
Shale and sand	890	929
Chalk	929	934
Sand and shale, showing oil and gas	934	940
Shale	940	970
Gumbo	970	980
Shale	980	996
Gumbo	996	1005
Sandy shale, showing gas	1005	1020
Gumbo	1020	1034
Shale	1034	1046
Gumbo	1046	1064
Sandy shale, showing gas, some fresh water	1064	1086
Gumbo, set 8″, open hole below	1086	1133
Extra hard rock	1133	1142
Sandy shale, showing gas and oil	1142	1148
Gumbo	1148	1180
Sandy shale	1180	1203
Sandy shale, showing oil and gas	1203	1220
Mixed shale	1220	1239
Gray gumbo	1239	1258
Boulders	1258	1270

Oakville:		
Blue lime	1270	1281
Blue gumbo	1281	1298
Gyp rock	1298	1301½
Gumbo and boulders	1301½	1318
Blue gumbo	1318	1335
Shale and boulders	1335	1352
Blue gumbo and talc	1352	1383
Lime boulders	1383	1400
Blue shale	1400	1416
Boulders and water sand	1416	1436
Blue gumbo	1436	1470
Gumbo and boulders	1470	1483
Rock and shale	1483	1540
Gumbo boulders	1540	1594
Hard sandy gumbo	1594	1614
Gumbo lime streaks	1614	1634
Hard shale	1634	1653
Sandy gumbo	1653	1673
Blue shale	1673	1700
Sandy gumbo	1700	1722
Gumbo lime	1722	1744
Shale, sand	1744	1764
Corrigan:		
Hard shale	1764	1781
Chalk, gyp, gumbo	1801	1819
Hard shale	1801	1819
Hard shale	1819	1859
Gumbo boulders	1859	1879
Pyrite of iron and shale	1879	1897
Limy shale	1897	1902
Soap-stone	1902	1910
Sandstone	1910	1913
Blue gumbo	1913	1916
Hard shale	1916	1926
Broken shale and oil showing	1936	1939
Blue shale	1939	1959
Blue sandy gumbo	1959	2012
Sand rock	2012	2032
Gumbo lime	2032	2055
Hard shale boulders	2055	2070
Frio:		
Hard shale	2070	2089
Hard shale and lime	2089	2114
Blue gumbo	2114	2130

Limy shale	2130	2171
Blue shale	2171	2175
Hard limy shale	2175	2234
Lime and shale	2234	2260
Hard shale and gumbo, green	2260	2293
Gumbo and boulders	2293	2329
Shale	2329	2332
Gumbo	2332	2370
Hard shale, green	2370	2392
Lime and hard shale	2392	2414
Hard shale	2414	2457
Gray shale, softer	2457	2483
Hard shale, shell	2483	2506
Hard shale, boulders of lime, etc.	2506	2527
Black gumbo, shells and lignite	2527	2705
Green marl	2705	2720
Fayette:		
Red marl	2720	2725
Sandstone	2725	

Log of the Lissie Petroleum Company's Well, Lee No. 1.....Location: S. ¼ of S. ¼ of N. ¼ of Section 21, G. H. & H. R. R. Survey, one mile south of Lissie, Wharton County, Texas.....J. W. Lee Lands. Drilling Dec. 10, 1920—July 8, 1921.

	Depth in Feet From	To
Lissie:		
Top soil	0	2
Red clay	2	22
Sand	22	37
Red clay	37	72
Sand and gravel	72	90
Red clay	90	103
Soft rock	103	103.5
Sand and gravel	103.5	130
Red clay	130	143
Lagarto:		
Lime rock	143	210
White clay	210	220
Sand rock	220	240
Sand and gravel	240	250
Medium rock	250	254
Gravel	254	260
Medium rock	260	298
Sand and gravel	298	318
Gray clay	318	360
Rock and gravel	360	380

Yellow clay	380	420
Sand and gravel	420	438
Rock and clay	438	450
Clay	450	456
Sand rock	456	481
Sand	481	488
Medium rock	488	548
Gumbo	548	587
Sand	587	610
Sand rock	610	632
Gumbo	632	700
Lime rock	700	702
Red shale	702	782
Sand rock	782	796
Shale	796	821
Lime rock	821	822
Sand rock	822	834
Hard gumbo	834	865
Sand rock, strong oil showing at 865-870 feet	865	880
Water sand	880	895
Yellow gumbo	895	905
Lapara:		
Blue shale	905	920
Sand rock	920	925
Gray shale	925	991
Rock and sand	991	993
Gumbo	993	1070
Sand and gravel	1070	1088
Gumbo	1088	1115

Log of O. K. Oil and Gas Company's Well.—Located three miles south-southwest of Eagle Lake, Colorado County, Texas.

	Depth in Feet From	To
River Alluvium:		
Surface clay	0	21
Lissie:		
Sand	21	31
Water sand	31	62
Lagarto:		
Limestone	62	202
Gumbo and broken rock	202	266
Shale, broken rock	266	308
Sandstone	308	318
Gumbo	318	361
Gumbo and broken rock (possibly lime nodules)	361	425

Blue shale	425	457
Sandstone	457	462
Gumbo	462	500
Sandstone	500	512
Gumbo	512	533
Gumbo and shale	533	575
Shale	575	617
Gumbo	617	630
Rock, (probably sandstone)	630	640
Blue shale	640	661
Gumbo	661	704
Sandstone	704	715
Blue gumbo	715	746
Sandstone	746	767
Blue gumbo	767	789
Soft rock (probably sandstone)	789	797
Blue gumbo	797	831
Soft rock	831	839
Blue gumbo	839	853
Blue shale	853	873
Soft rock	873	883
Hard rock	883	893
Hard rock	893	908
Shale	908	913
Sandstone, rock sand	913	933
Hard rock and gumbo	933	953
Rock	953	973
Gumbo	973	993
Hard rock (sandstone)	993	1000
Shale	1000	1020
Rock	1020	1027
Gumbo	1027	1047
Gumbo	1047	1093
Gumbo	1093	1113
Soft rock	1113	1133
Hard rock	1133	1143
Gumbo	1143	1155
Soft rock	1155	1176
Gumbo	1176	1197
Soft limestone	1197	1218
Hard sand	1218	1246
Oakville:		
Hard, blue gumbo	1246	1405
Hard sand	1405	1454
Hard, blue gumbo	1454	1494
Hard sand	1494	1506
Bottom-gumbo	1506	

Log of the Texas Company's Schaffner well No. 1. Located two- and one-half miles east of Cat Spring, Austin County, Texas.

	Depth in Feet From	To
Lissie:		
Not recorded	0	50
Sand and clay	50	135
Sand and boulders	135	183
Gumbo	183	210
Sand and boulders, hard	210	235
Gumbo	235	285
Sand and boulders	285	315
Gumbo and boulders	315	445
Sand and boulders	445	475
Lagarto:		
Gumbo	475	495
Sand and boulders	495	510
Gumbo and boulders	510	650
Shale and boulders	650	680
Sand and shale, hard	680	700
Gumbo	700	784
Sand	784	794
Gumbo and boulders	794	855
Sand and shale, medium	855	875
Gumbo and boulders	875	905
Sand and boulders, hard	905	917
Gumbo	917	1027
Sand and boulders	1027	1045
Sand, hard	1045	1055
Gumbo and boulders	1055	1070
Gumbo, blue, hard	1070	1115
Gumbo and gypsum	1115	1165
Gumbo	1165	1222
Lapara:		
Sand and boulders, hard	1222	1238
Gumbo and boulders	1238	1323
Sand, hard	1323	1330
Gumbo	1330	1344
Sand, hard	1344	1353
Gumbo	1353	1388
Gumbo and gypsum	1388	1524
Gumbo	1524	1558
Shale and sand	1558	1562
Gumbo and gypsum	1562	1594
Rock	1594	1596

Shale and sand	1596	1614
Gumbo	1614	1662
Rock	1662	1665
Gumbo	1665	1737
Shale, sand and gypsum	1737	1753
Gumbo	1753	1760
Gumbo and gypsum	1760	1790
Oakville:		
Gumbo	1790	1873
Shale	1873	1877
Gumbo	1877	1908
Sand	1908	1934
Gumbo	1934	1944
Sand and shale	1944	1953
Gumbo	1953	1966
Gumbo and gypsum	1966	2000
Gumbo	2000	2022
Shale	2022	2039
Gumbo	2039	2073
Sand and shale	2073	2081
Gumbo	2081	2311
Sand and shale	2311	2342
Gumbo	2342	2390
Sand, hard, and shale	2390	2395
Gumbo	2395	2432
Sand and shale, hard	2432	2440
Corrigan:		
Gumbo and gypsum	2440	2470
Shale and sand	2470	2484
Gumbo and gypsum	2484	2496
Drilling in gumbo		
Gumbo and gypsum	2496	2500
Gumbo	2500	2550
Sand and shale	2550	2559
Gumbo	2559	2582
Shale and sand	2582	2610
Gumbo	2610	2640
Sand and shale	2640	2653
Gumbo	2653	2736
Shale and sand	2736	2744
Gumbo	2744	2768
Hard sand	2768	2774
Gumbo	2774	2779
Gumbo and hard sand	2779	2796
Gumbo	2796	2802
Sand and shale	2802	2811

Gumbo and gypsum	2811	2842
Gumbo	2842	2942

Log of the Water Station Well, Glidden, Colorado County, Texas.

	Depth in Feet From	To
Lissie:		
Clay	0	12
Sand	12	21
Lagarto:		
Hard rock and gravel	21	60′ 10″
Flint rock	60′ 10″	60′ 11″
Clay and gravel	60′ 11″	70′ 11″
Cement gravel	70′ 11″	83
Hard sand, rock and gravel	83	104
Clay and gravel	104	125.1
Clay	125.1	137
Gumbo	137	145
Packed sand	145	153
Pyrites iron	153	153′ 4″
Sand rock	153′ 4″	156′ 4″
Gumbo	156′ 4″	177′ 2″
Lime rock	177′ 2″	178′ 2″
Gumbo	178′ 2″	200′ 10″
Rock pyrites of iron	200′ 10″	203′ 10″
Gumbo	203′ 10″	210′ 8″
Gravel, flint rock, pyrites iron	210′ 8″	226′ 0″
Clay and gumbo	226	258
Stone and gravel	258	261′ 4″
Gumbo and gravel	261′ 4″	312′ 4″
Rock	312′ 4″	312′ 10″
No record	312′ 10″	316′ 10″
Hard layer	316′ 10″	317′ 4″
No record	317′ 4″	321′ 4″
Clay and gravel	321′ 4″	331′ 6″
Gumbo	331′ 6″	341′ 6″
Soft blue clay	341′ 6″	351′ 2″
Gravel	351′ 2″	401′ 2″
Gumbo	401′ 2″	443′ 4″
Sandy shale	443′ 4″	470
Gumbo and gravel	470	489
Sand	489	504′ 8″
Gumbo	504′ 8″	560′ 11″
Hard shale	560′ 11″	564′ 11″
Gumbo	564′ 11″	602
Sand rock	602	609

	Depth in Feet			
	From		To	
No record	609		613	
Hard layer	613		614	
Blue clay and gravel	614		627′	9″
Hard layer	627′	9″	628′	9″
Gumbo	628′	9″	656′	9″
Fine sandstone	656′	9″	708.5	
Gumbo	708.5		763′	1″
Soft sandrock	763′	1″	767′	1″
Clay and white rock	767′	1″	782′	1″
Hard sandrock	782′	1″	804′	9″
Gravel	804′	9″	923	

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INDEX

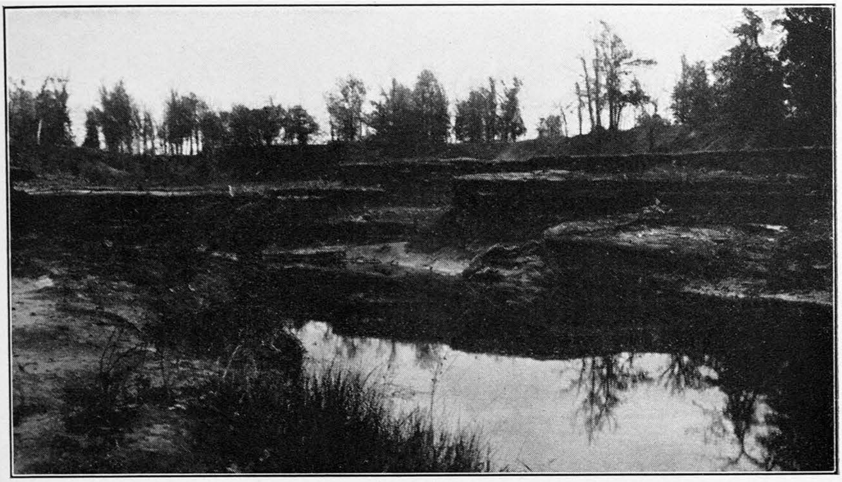
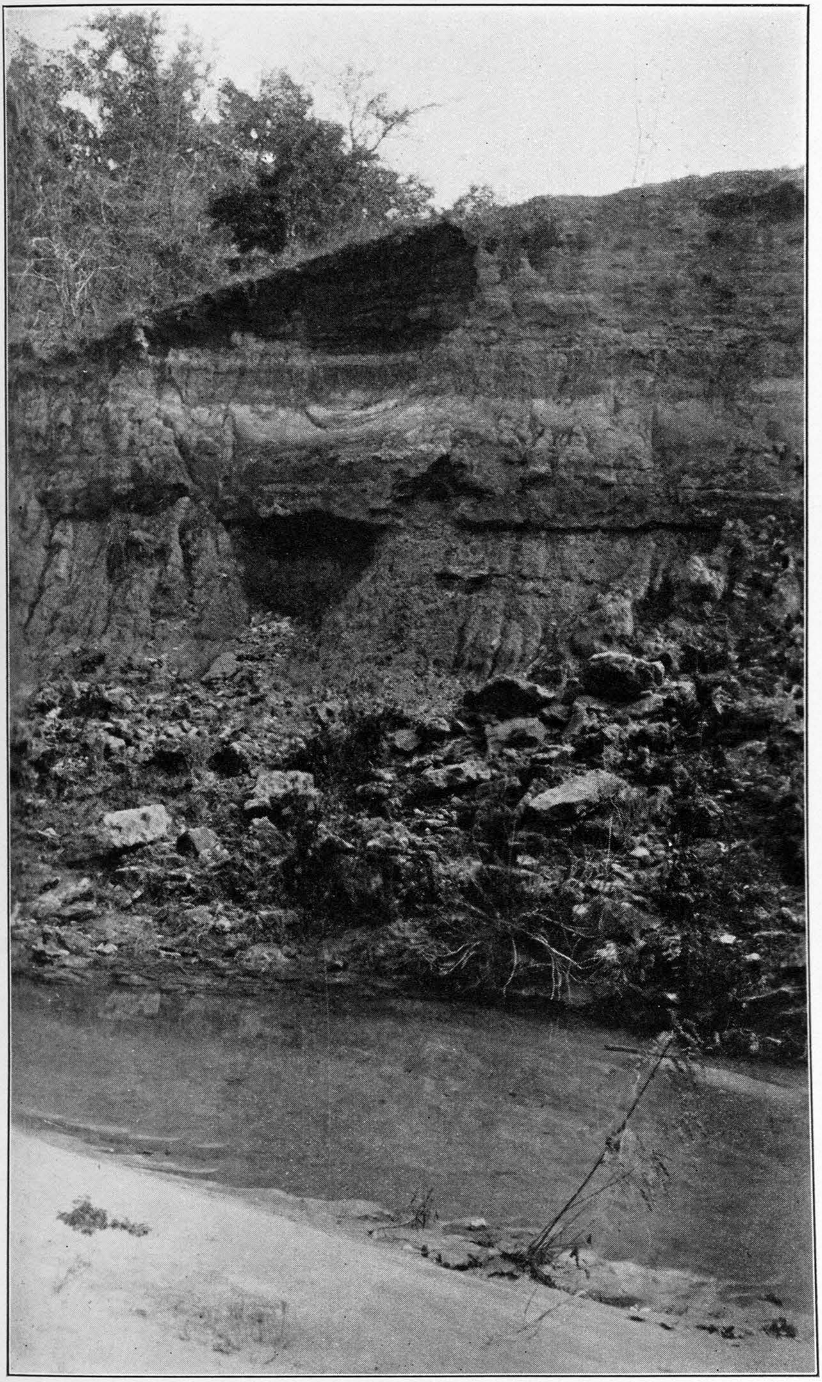


Fig. 1. Outcrop of Lagarto thin-bedded sandstone and clay on South Harvey Creek, one-fourth mile west of Borden.

Fig. 2. Minor cross-bedding in Lagarto soft sandstones and sands, one and one-half miles north of Borden. (Protohippus perditus locality). Pick marks shown near bottom of photograph.



Lagarto-Papara sandstone, sand and clay outcrop on Brushy Creek, three miles southeast of Ellinger. (Fossil Palm locality).

Typical outcrop of Lagarto joint-clay showing calcareous concretions in wash-out north of highway one mile east of Borden.

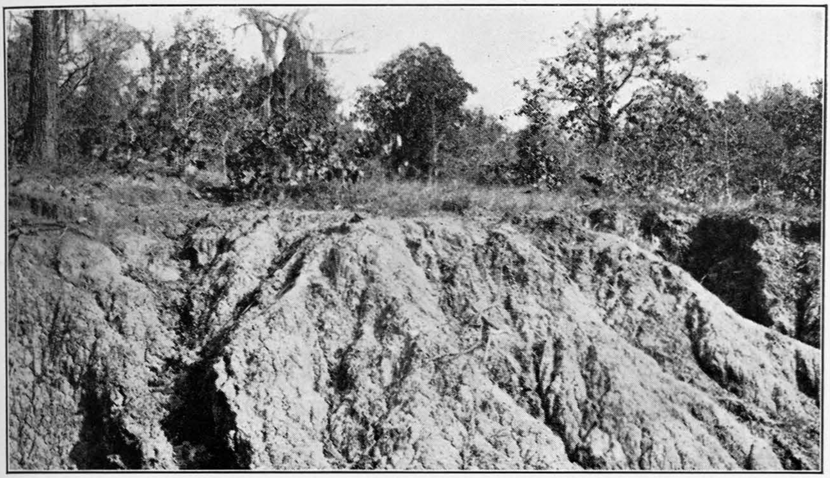


Fig. 1. Outcrop of Lissie red and yellow, gravelly sandy clay on Sealy-Alleyton road, four miles northeast of Alleyton. Contains numerous ferruginous concretions.

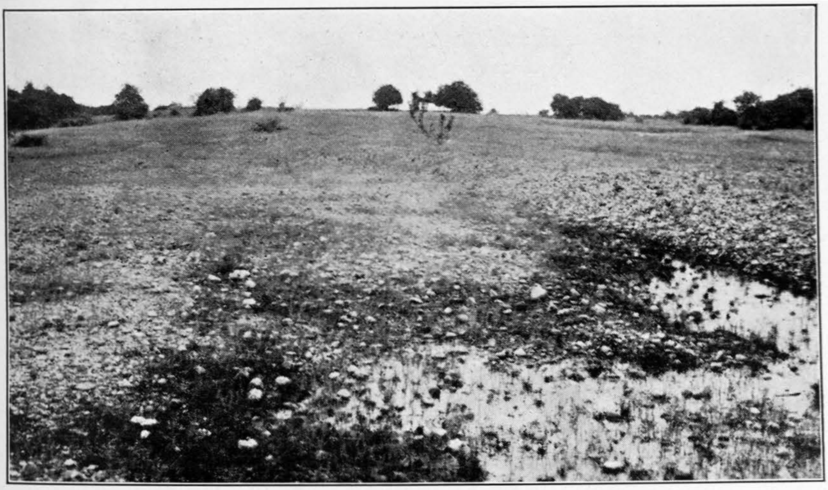


Fig. 2. Lower Lissie gravel on top of Rocky Hill, three miles southwest of Glidden. This hill is a remnant of the sixth Colorado River terrace.

Fig. 1. Typical Lower Lissie Post Oak Woods on Alleyton-Sealy road, four miles northeast of Alleyton.

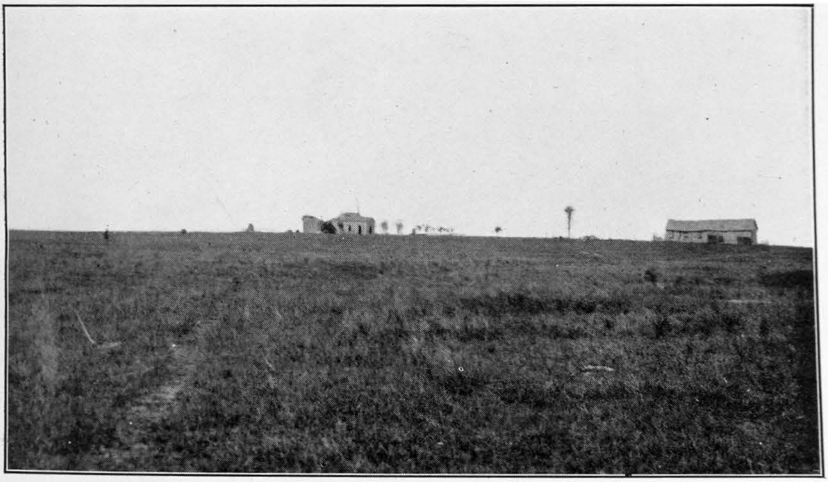


Fig. 2. Large mound, possibly a salt dome, on Section 45, I. & G. N. Ry. Survey, eight miles west-southwest of Garwood.

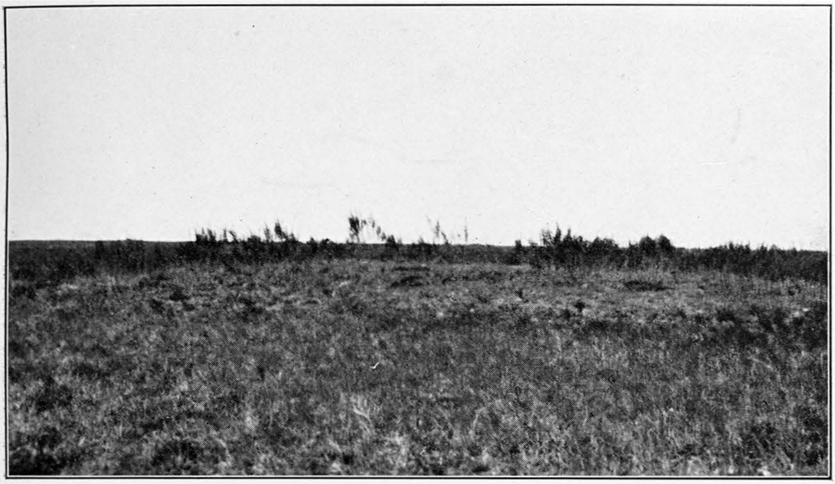


Fig. 1. Small prairie mound, two miles south of Altair on Upper Lissie Prairie.

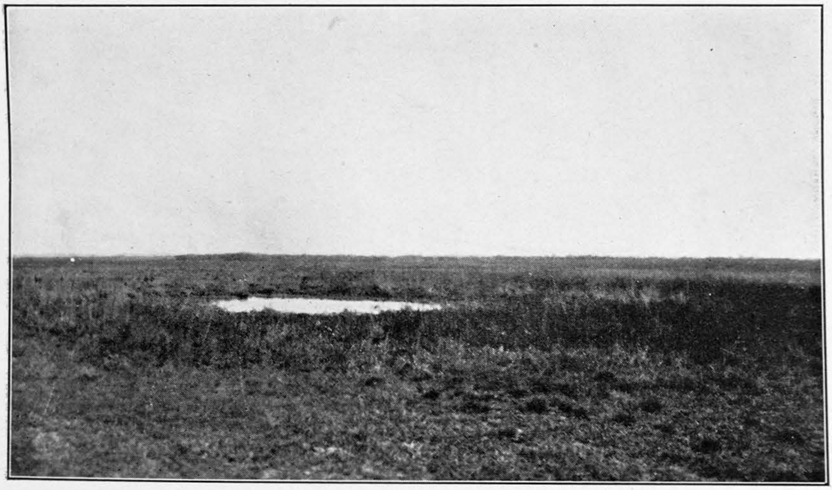


Fig. 2. Pond occupying site of sunken mound on Upper Lissie Prairie, two miles north of Altair.

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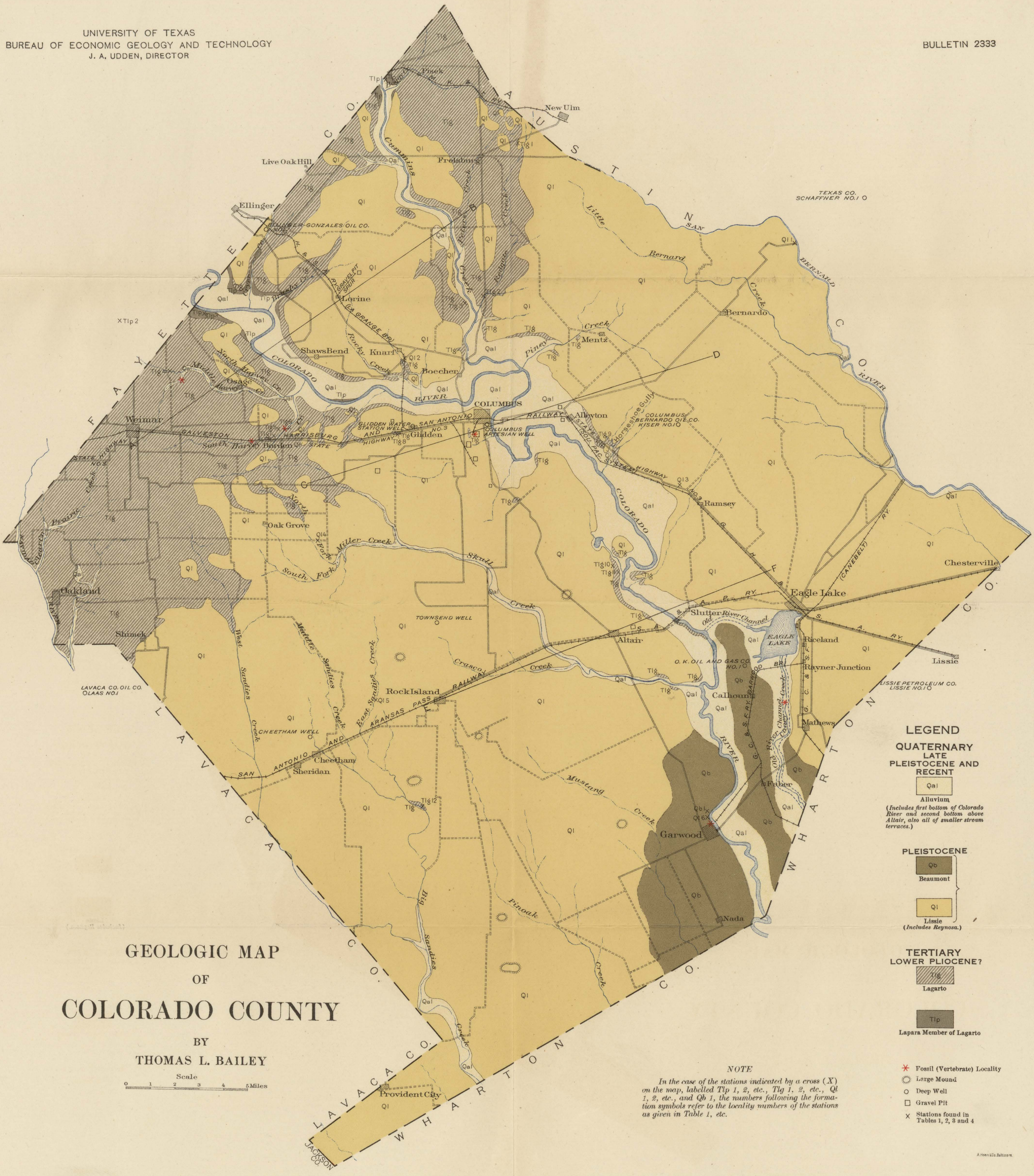

GEOLOGIC MAP
OF
COLORADO COUNTY
BY
THOMAS L. BAILEY

Scale
0 1 2 3 4 5 Miles

LEGEND

QUATERNARY
LATE PLEISTOCENE AND RECENT

Qal — Alluvium (Includes first bottom of Colorado River and second bottom above Altair, also all of smaller stream terraces.)

PLEISTOCENE

Qb — Beaumont

Ql — Lissie (Includes Reynosa.)

TERTIARY
LOWER PLIOCENE?

Tlg — Lagarto

Tlp — Lapara Member of Lagarto

✳ Fossil (Vertebrate) Locality
Large Mound
○ Deep Well
□ Gravel Pit
× Stations found in Tables 1, 2, 3 and 4

NOTE

In the case of the stations indicated by a cross (X) on the map, labelled Tlp 1, 2, etc., Tlg 1, 2, etc., Ql 1, 2, etc., and Qb 1, the numbers following the formation symbols refer to the locality numbers of the stations as given in Table 1, etc.